DOMINION OF CANADA
DEPARTMENT OF AGRICULTURE
ENTOMOLOGICAL BRANCH
C. GORDON HEWITT, DOMINION ENTOMOLOGIST

THE CABBAGE ROOT MAGGOT AND ITS CONTROL IN CANADA

WITH

Notes on the Imported Onion Maggot and the Seed-corn Maggot

BY

ARTHUR GIBSON
Chief Assistant Entomologist

AND

R. C. TREHERNE
Field Officer

BULLETIN No. 12

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OTTAWA
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92548—1

Ottawa, February 8, 1916.

To the Honourable,
The Minister of Agriculture,
Ottawa, Ont.

Sir,—I have the honour to submit for your approval Entomological Bulletin No. 12, entitled "The Cabbage Root Maggot and its Control in Canada, with notes on the Imported Onion Maggot and the Seed-corn Maggot," which has been written by Mr. Arthur Gibson, Chief Assistant Entomologist, and Mr. R. C. Treherne, Field Officer in charge of the Entomological Laboratory at Agassiz, B.C.

From year to year the loss caused by Root Maggots assumes greater proportions owing largely to the increase in the acreage under cultivation. From Nova Scotia to British Columbia and north to the Yukon the injuries of the different species, but particularly of the Cabbage Root Maggot, to roots and other field and garden crops are reported to us; in many cases the losses are considerable and discouraging. For a number of years my predecessor, Dr. James Fletcher, experimented with various possible remedial measures. In 1910, we commenced a careful study of the various remedial measures recommended for the control of Root Maggots and of remedies that suggested themselves to us, and these experiments have been continued annually at Ottawa for six seasons by Mr. Gibson. During the last three years Mr. Treherne has also studied the life-history and methods of control of the Cabbage Root Maggot at Agassiz, B.C. The results of this work are given in this Bulletin. The carrying on of these experiments has naturally resulted in the accumulation of a very large amount of data; these have been summarised and translated into words. In many cases the results have been contradictory and inconclusive and their rejection has been necessary.

The recommendations that are made are based, with few exceptions, on the results of our own experimental work. There are a number of promising lines of investigation which have opened up, but we feel that, in view of the increasing demand throughout Canada for the information now given in this bulletin, we should not postpone its publication longer.

I have the honour to be, Sir,

Your obedient servant,

C. GORDON HEWITT.

Dominion Entomologist.

92548—2

NOTE.

Farmers and others are invited to send specimens of insects which are found causing injuries to their crops. Such specimens should be enclosed with a supply of food plant or grass in a tin or wooden box (not a paper box) which may be mailed "Free", up to 11 ounces in weight, if addressed to the Dominion Entomologist, Department of Agriculture, Ottawa. In all cases the specimens should bear the address of the sender, and should be accompanied by a letter giving the crops which are being attacked and the extent of the damage.

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By Arthur Gibson, *Chief Assistant Entomologist*,

and

R. C. Treherne, *Field Officer*.

SUMMARY.

In spring when cabbages and cauliflowers are set out, or when radishes, onions, beans and other plants appear above the soil, small flies, somewhat resembling the common house-fly but rather smaller and more slender, may be seen flying about close to the ground, depositing small, white, elongated eggs on the stems of the plants or adjacent thereto. These eggs hatch in a few days and the small, white maggots at once burrow down and destroy the roots. In the case of the Cabbage Root Maggot, there are three or four generations during the season. The Imported Onion Maggot also has several generations, and injury by these species may continue from May until autumn. The chief damage is effected in May and during June. Early grown crops are particularly attacked, some seasons whole fields of these being entirely ruined. Injury by the Seed-corn Maggot is largely confined to the seedlings of such plants as corn, beans and peas. The annual loss caused by these insects in Canada amounts to many thousands of dollars.

The larvæ of the above three species, which are popularly known as root maggots, are similar in appearance, being whitish in colour, rather blunt at one end and pointed at the other end, and when mature are about from one-quarter to one-third of an inch long. It is in this stage that the insect is destructive and known to the farmer or vegetable grower.

Several important parasitic and predacious enemies prey upon the root maggots, but these unfortunately cannot be relied upon to control outbreaks of these insects, and therefore artificial methods of control become necessary.

Among the artificial methods, the screening of seed beds to prevent the female flies gaining access to the plants to deposit their eggs is important. Cabbages and cauliflowers when transplanted in the field may be protected by placing around the stems a disc made from one-ply tarred felt paper. In small gardens applications of decoctions of white hellebore, pyrethrum insect powder or of a carbolic wash mixture have been found of value. Under field conditions the protection of such crops as onions, turnips, corn, peas and beans from the ravages of root maggots has proved to be a difficult problem but recent experiments with poisoned baits to destroy the Imported Onion Maggot Fly have been found to give much promise.

Fall ploughing and rotation of crops while, of course, being excellent agricultural practices, have their limitations so far as the control of root maggots is concerned; such cultural methods, however, as soil cultivation and the use of fertilizers undoubtedly assist considerably artificial control measures. Owing to the fact that root maggot flies are known to lay their eggs on stable manure it is advisable, in spring, to avoid the use of such fertilizer as much as possible.

92548—3½

INTRODUCTION.

Among the destructive root-infesting insects of importance to the farmer and vegetable grower, the Cabbage Root Maggot (*Phorbia brassicæ* Bouché), the Imported Onion Maggot (*Hylemyia antiqua* Mg. = *Phorbia ceparum* Mg.), and the Seed-corn Maggot (*Phorbia fusciceps* Zett.), easily take first rank. The Cabbage Root Maggot, often referred to as the Cabbage Maggot, the Radish Maggot or the Turnip Maggot, attacks freely plants of the Cabbage Family; the Imported Onion Maggot feeds early in the season on that portion of the onion plant below the ground, and later bores into the bulbs; the Seed-corn Maggot infests the seeds and seedlings of corn, beans and peas, and occasionally attacks cabbage, radish and a few other plants.

Fields of the above mentioned crops have, in certain seasons, been completely destroyed by the ravages of these root maggots. As such injury is so well known to farmers and market gardeners it is unnecessary to refer in detail to the enormous annual losses in Canada caused by these destructive insects. Suffice it to say that as a class they are of decided economic importance.

Fig. 1.—Eggs of Cabbage Root Maggot Fly, on stem of cabbage, enlarged 11 times. (Original).

Fig. 2.—Egg of Cabbage Root Maggot Fly, enlarged 40 times, showing groove and ridges. (Original).

HISTORICAL.

Injury by root maggots has been known in Canada for many years. The Cabbage Root Maggot, the Imported Onion Maggot and the Seed-corn Maggot are all of European origin. It is not known definitely when these insects reached Canada. The Cabbage Root Maggot, *Phorbia brassicæ* Bouché, was first recorded in the United States in 1835 (1). In 1875, Couper (2) reported that the Imported Onion Fly, *Hylemyia antiqua* Mg., was a terrible pest to the onion growers throughout the extent of the Dominion and that another species had been destroying cabbages in the neighbourhood of Montreal, Que. This report undoubtedly referred to injury caused by the Cabbage Root Maggot. It was not until 1885, however, that the ravages of the latter insect in Canada attracted widespread attention. In that year, Fletcher (3) stated that it destroyed from 25 to 75 per cent. of the cauliflowers grown. There can be no question that both the Cabbage Root Maggot and the Imported Onion Maggot were present in injurious numbers many years previous to 1875, otherwise these insects could not have become so well established throughout Canada. The adult of the Seed-corn Maggot, *Phorbia fusciceps* Zett., was recorded, from Martin Falls, Ont., and the Province of Nova Scotia, in Walker's List of Diptera in the British Museum, part IV., the title page of which bears the date 1849. It was not,

however, until 1885, that injury by the larvæ attracted attention. In that year Jack (4) found the maggots at Chateauguay, Que., causing much loss in a field of golden wax-beans. Fortunately, this maggot is not a regularly-occurring pest, but in years of abundance much damage takes place, particularly to corn and beans. This species also occurs in every province in Canada.

THE CABBAGE ROOT MAGGOT, *Phorbia brassicæ* Bouché.

LIFE-HISTORY.

The Egg.

Description.—The egg is very small but easily seen on the plants or on the soil near them. In length it is about 1 mm. (one twenty-fifth of an inch) curved in outline on one side; in colour, white, with distinct ridges; in shape, cylindrical, pointed at one end and rather blunt at the other. On one side of the egg there is a distinct groove which is wider and deeper at the blunt end.

Duration of stage.—Full and complete records on the duration of the individual egg stage and the degree of egg fertility have been obtained during the course of study of this insect. The following table represents these two points arranged on the basis of an examination of 2,113 eggs as studied at Agassiz, in the Province of British Columbia. Inasmuch as these records were obtained from a consecutive series of experiments carried over the entire summer of 1915, at Agassiz, B.C., involving all possible generations they are mentioned here in preference to similar records obtained at other points in Canada. From a study of the duration of the egg stage it is clear that the period varies from three to five days, on an average, and this finding appears to coincide with available records in eastern Canada and in the United States.

TABLE I.—SUMMARY OF THE DURATION OF THE INDIVIDUAL EGG STAGE AND THE DEGREE OF FERTILITY, AGASSIZ, B.C., 1915.

Period.	Number of eggs Studied.	Average Number of days required to Hatch.	Per cent Fertility.
April 19–May 7	261	4·87	88·2
May 21–May 31	66	4·90	83·6
Month of June	371	4·70	85·0
Month of July	709	3·80	84·0
Month of August	380	5·03	89·9
Month of September	326	4·80	91·0
	2,113	4·7	86·9

From this we assume that the egg stage lasts on the average of 4.7 days and that the high egg fertility record is maintained throughout the summer, possibly, it would seem, even increasing with the advance of the season. All eggs do not, however, maintain such an even degree of hatching as the above table indicates. In our observations it was noted that the egg-stage lasted from 2 to 10 days; in fact our study indicated that

1·9	per cent	hatched	in 2 days.	45·6	per cent	hatched	in 6 days.
3·7	,,	,,	3 ,,	6·1	,,	,,	7 ,,
16	,,	,,	4 ,,	0·4	,,	,,	8 ,,
25·8	,,	,,	5 ,,	0·5	,,	,,	10 ,,

All these above records were obtained under supposedly ideal conditions, that is to say, from eggs hatched on slightly moistened blotting paper in vials

under ordinary atmospheric conditions. Uniform incubator temperatures from 27 deg. C. to 30 deg. C. gave a variable hatching, also, from 3 to 5 days. To determine to what extent a variation may occur in the percentage of larvæ hatching from the eggs, 509 eggs were kept under observation under ideal condi-

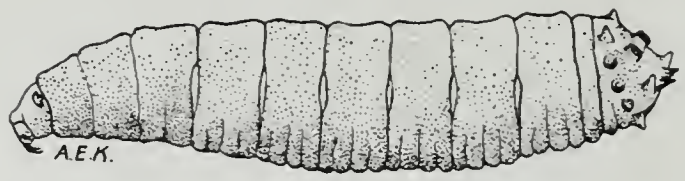

Fig. 3.—Cabbage Root Maggot, side view: enlarged 7 times. (Original).

tions, such as those just mentioned, in comparison with perfectly dry conditions as would be obtained on dry blotting paper in vials. The following results were noted:

258	eggs kept under moist conditions:	
	average number of days required to hatch	3·7
	per cent. hatched	95·
251	eggs kept under dry conditions:	
	average number of days required to hatch	3·3
	per cent. hatched	50·

The average of 50 per cent. noted under dry conditions, we think, however, is rather high, our experiments, at Agassiz, B.C., indicating that exceptional high temperatures decrease the percentage of eggs which hatch.

The Larva.

Description.—The mature or full-grown larva is about 8 mm. in length (one-third of an inch). It is whitish in colour, flattened at one end and tapering to the other or head end. The segments are distinctly divided. At the blunt, or caudal, end are 12 fleshy tubercles, the pair nearest the centre being larger than the others, and each bearing two points, which are dark in colour. In the centre are two conspicuous, raised, reddish-brown spiracles. In compari-

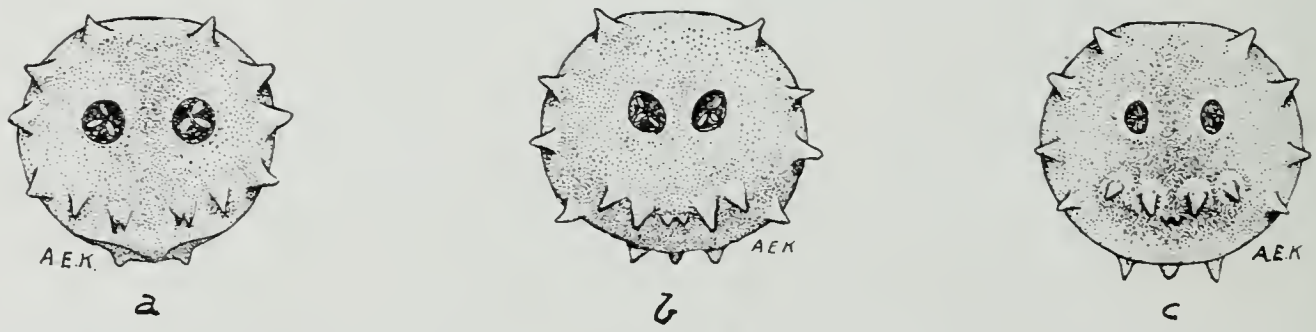

Fig. 4.—(a), Caudal end of Cabbage Root Maggot; (b) of the Imported Onion Maggot; and (c) of the Seed-corn Maggot; showing arrangement of fleshy tubercles and central spiracles; all much enlarged (Original).

son with the Imported Onion Maggot the caudal end is more flattened and abrupt. The arrangement of the fleshy tubercles is shown in figure 4 (a). From the head project a pair of black, hook-like, mandibles or jaws, A short distance from the head on either side, is a fan-like process; these are the spiracles and communicate with the tracheæ, or "air tubes."

Duration of stage.—Obviously the question of the length of the larval stage is of great importance in its practical relation to the injury that the larvæ effect, on account of the fact that the damage caused to crops by this insect is only brought about in the larval form.

Those who have studied this insect in the United States and in Europe state that the length of the larval stage lasts from three to four weeks. This corresponds with our records in Canada, which indicate that the larval stage varies between 19 and 32 days. It will not be necessary to detail our notes in this connection as the duration of the individual stage seems thus well established. It is more important to determine the feeding life of the broods of larvæ as they occur, for it is not the individual feeding action that causes such havoc to crops but the concerted action of many larvæ over a considerable period of time. The number of generations, however, is dealt with on pages 17-20.

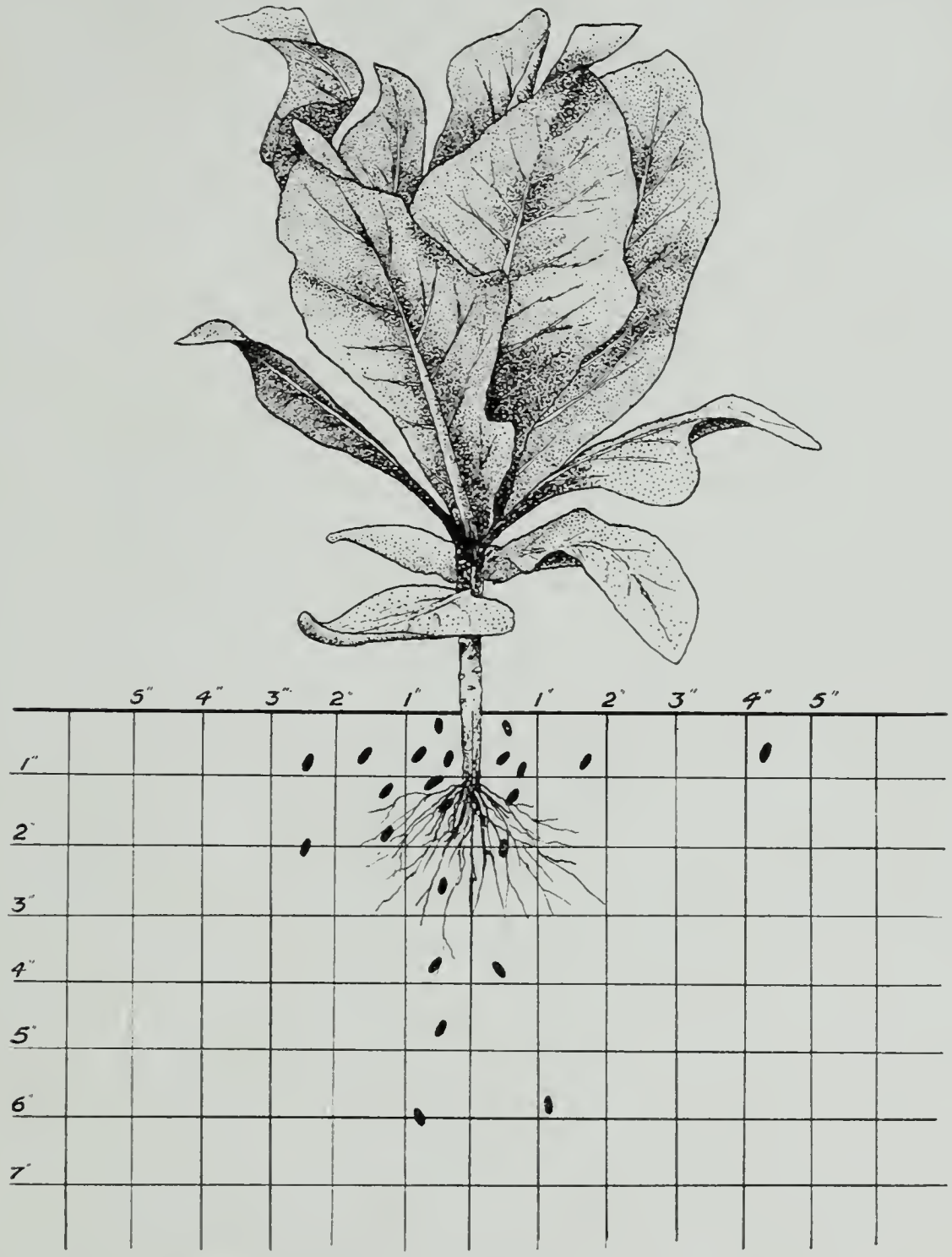

FIG. 5.—Showing position and depths of puparia of the Cabbage Root Maggot, found around one plant. (Original).

Pupation.—When the larva has become full grown, having completed its feeding, it seeks a suitable position in which to change to the puparium stage preparatory to the emergence of the adult fly.

The puparium may be either imbedded in the tissues of the root where the larva completed its feeding or close to the root in the wet soil produced by the feeding of the maggots, or again, the larva may migrate and pupate some distance in the adjoining soil, possibly as far as 4 or 5 inches from the roots.

The place of pupation in the soil, however, may vary considerably according to the depth of feeding. In our investigations at Ottawa, Ont., we found the over-wintering puparia at depths in the soil varying from 1 inch to 9 inches. In April, 1914, 146 puparia were removed from the soil. The following table indicates the percentage of puparia found at the various depths:

TABLE II.—SHOWING DEPTH OF PUPARIA IN SOIL.

Depth in Inches.	1	1¼	1½	1¾	2	2¼	2½	2¾	3	3¼	3½
Percentage of puparia.....	4·26	2·73	3·41	1·36	6·16	6·16	6·16	0·68	14·38	3·41	7·53
Depth in Inches.	3¾	4	4¼	4½	4¾	5	5¼	5½	5¾	6	6¼
Percentage of puparia.....	4·26	11·98	0·68	12·32	3·41	6·85	0·68	2·05	0	0	0
Depth in Inches.	6½	6¾	7	7¼	7½	7¾	8	8¼	8½	8¾	9
Percentage of puparia.....	0·68	0·68	0	0	0	0	0·68	0	0	0	0·68

From observations made in the spring of 1914, there is evidently no constant position in which the larvæ pupate. Puparia were found in all positions, from vertical to horizontal, at varying depths.

From experiments conducted by Washburn (5) in burying puparia at different depths, it was surmised that the flies were not able to penetrate through six inches of soil under as near natural conditions as possible. In experiments,

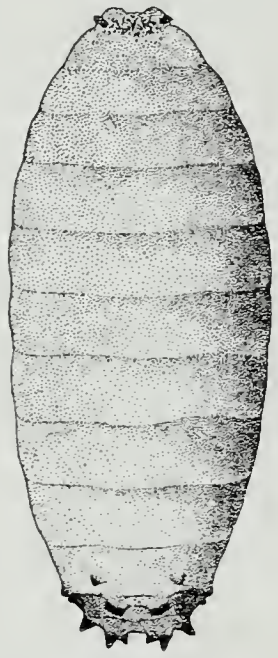

FIG. 6.—Puparium of Cabbage Root Maggot; enlarged 8 times. (Original).

however, conducted at Ottawa, Ont., flies emerged at the depth of nine inches, as shown in the following table:

TABLE III.—SHOWING EMERGENCE OF FLIES FROM PUPARIA BURIED AT DIFFERENT DEPTHS.

Date Collected.	Number Puparia.	Depth buried in inches.	Number Emerged.	Per centage emerged.
May 1.....	15	4	6	40
	10	5	5	50
	25	9	5	20

In the above experiment at Ottawa the puparia were placed in large open-mouthed jars on $1\frac{1}{2}$ inches of earth. The puparia were then covered with soil to the depth stated in the table, which soil was packed tightly by jarring. From this experiment and also owing to the fact that we have found puparia in the field 9 inches beneath the surface of the soil, we are justified in concluding that the adult flies are able to penetrate to the surface from such depth and develop.

The Puparium.

Description.—The puparium, within which the maggot changes to the adult fly, varies from light to dark reddish-brown in colour, and in shape is as shown in fig. 6. In length it is from 5 to 6 mm. (one-quarter of an inch), although some puparia are frequently found of shorter length. The puparium, which is simply the hardened contracted skin of the maggot retains the tubercles which occurred at the blunt end of the larva. It is, therefore, usually possible to determine the insect from this character.

Fig. 7.—Male of the Cabbage Root Maggot Fly; enlarged about 3 times. (Photograph by J. T. Wadsworth).

Fig. 8.—Female of the Cabbage Root Maggot Fly, enlarged about 3 times. (Photograph by J. T. Wadsworth).

Duration of stage.—The length of time the insect remains within the puparium during the summer varied in individual experiments conducted at Agassiz, B.C., from 15 to 18 days. The duration of the puparium stage, however, as shown by the following table, far exceeds this latter period.

TABLE IV.—INDICATING THE LENGTH OF PUPARIUM STAGE DURING SUMMER AND AUTUMN.

Number of puparia under observation.	Date puparia collected.	Dates of fly emergence.	Number of days.
74	July 6	July 10—July 26	4—19
80	July 31	Aug. 5—Aug. 27	5—27
70	Aug. 27	Aug. 28—Sept. 25	2—30
75	Sept. 1	Sept. 8—Sept. 26	8—26

It may readily be supposed that puparia formed in close proximity to the surface of the soil in more direct contact with the rays of the sun during the

summer months would produce flies sooner than puparia deep in the soil away from such temperature influences. Further, there are indications that there is a marked difference in the length of the puparium stage in the spring and summer as compared to late summer and autumn. In the late generation which passes the winter in the puparium stage there is a marked difference in the dates, in the following spring, at which the flies emerge. From puparia collected in the field at Ottawa, Ont., on April 25, 1914, flies emerged in the outdoor insectary from May 20 until July 6. In the field, however, the adult flies have been observed earlier than this at Ottawa, and as early as April 8, at Agassiz, B.C. In our insectary at the latter place no flies emerged from puparia after September 27, although until this date the flies had been emerging freely from puparia

Fig. 9.—(a), Side view of arrangement of hairs and bristles on femur and tibia of the hind leg of the Cabbage Root Maggot Fly; (b) of the Imported Onion Maggot Fly and (c) of the Seed-corn Maggot Fly; all much enlarged. (Original).

(286) collected in that month. Indicating the marked difference of climate at Agassiz, B.C., and Ottawa, Ont., in March, 1915, it may be here stated that at Agassiz the monthly mean temperature was 41·02 F. and at Ottawa 19·36 F.

The Adult.

Description of the male.—The male fly is about one-quarter of an inch in length from the tip of the head to the end of the abdomen, the body and legs being of a dark ash-gray colour, and rather thickly covered with black bristles. On the back of the thorax, the central portion of the body to which the two wings

are attached, are three blackish, rather broad, bands, the central one of which continues along the back of the abdomen. The eyes, which nearly touch each other in this sex, are of a reddish-purple colour. At the base of the femur (the upper portion) of each hind leg there is a conspicuous cluster of rather long bristles, and this is a character which is used to separate the male of this species from the male of closely allied species. These bristles are shown in figure 9 (a).

Description of the female.—The female fly is in general appearance much the same as the male. It is of a lighter colour and the eyes are rather widely separated. The abdomen is shaped differently from that of the male, being slightly longer and pointed at the end.

Duration of life.—A series of experiments were conducted at Agassiz, B.C to determine the average length of the life of the adults, with results given in the following table:—

TABLE V.—LENGTH OF THE LIFE OF INDIVIDUAL FLIES.

Dates on which emergence took place.	Number of adults.	Average length of life in days.	Variation in length of individual life.
June 26—July 1	62	3·5	2— 5
July 10—July 26	53	4·8	2— 7
July 16—July 24	11	4·3	3— 7
July 17—July 28	33	6·2	3—10
Aug. 5—Aug. 25	57	5·9	3—9
Aug. 28—Sept. 27	92	9·0	7—25

The above table would indicate that the length of the life of the individual adult increases as the season advances. The question as to whether the length of the life may be prolonged by feeding the flies with sweetened mixtures does not indicate that life may be extended very much over adults deprived of food, hence the table given is a compilation from results from flies both fed and starved after emergence.

The proportion of sexes.—It is interesting to note that, in the study of the Cabbage Root Maggot at Agassiz, B.C., of 408 adult flies reared, 197 were males and 211 females. This gives a percentage of 51·7 females and 48·3 males. There are no indications that there is any increase in either one sex at any period during the season.

Recently Mr. E. O. Essig, in his work on Injurious and Beneficial Insects of California, 2nd Edition, 1915, refers to the fact that the species of root maggot in California previously recorded by him as *Phorbia brassicæ*, was in reality *Phorbia planipalpis*. Mr. Essig bases his statement on the authority of Dr. J. M. Aldrich.

Dr. Aldrich has identified adult flies bred from radishes, cabbages, and cauliflowers at Agassiz, B.C., as *Phorbia brassicæ*. We have no records of *Phorbia planipalpis* occuring injuriously in British Columbia.

DEVELOPMENT.

Number of Generations.

We have found it an extremely difficult matter to determine with absolute accuracy the exact number of generations that occur in a season. In all our

work with this insect we have not been able to breed a series of flies continuously through the entire summer from the progeny of flies reared from overwintering puparia. From the foregoing records of the life-history of the insect we have observed that under conditions prevailing at Agassiz, B.C., the individual egg stage covered a period of from 2 to 10 days; the larval stage from 19 to 32 days; the puparium stage from 15 to 18 days and the adult stage from 3 to 9 days. Hence we gather that the length of the various stages from egg to adult covers a period of at least between 39 days and 69 days. As stated below eggs may be deposited on April 10, in a favourable spring and egg laying may be continuous from that date until October 22, a period approximately of six months. At Ottawa, Ont., we have a minimum record of 37 days from the time the eggs were laid in spring until the fly appeared.

It would appear, therefore, on theoretical grounds and by analogy, that at least three generations, and possibly four occur during the year in British Columbia. It is highly probably that in certain seasons a percentage of the puparia of the third generation pass the winter in such condition, the flies not emerging until the spring of the following year. As mentioned on page 16 no flies emerged in an outside insectary after September 27, although emergence was continuous previous to that date.

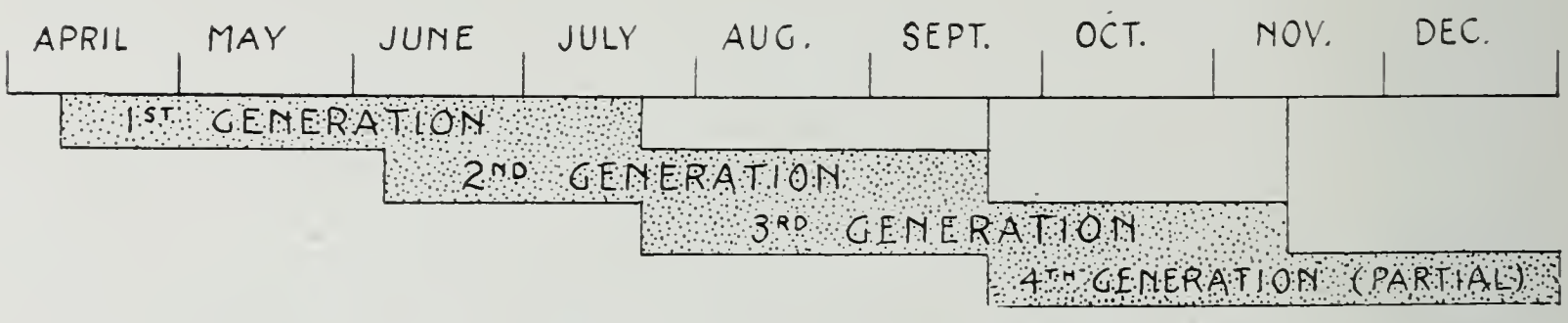

FIG. 10.—The approximate disposition of generations of the Cabbage Root Maggot, in the Lower Fraser Valley, B.C., 1915. (Original).

First generation.—The first generation arises from eggs deposited by flies emerging during the first favourable days of spring from overwintering puparia. The date when the first egg is laid varies considerably according to the season. It has been observed that oviposition may commence in the first week of April (Agassiz, B.C.) provided weather conditions are suitable. In an ordinary season oviposition is well under way during the last quarter of that month. In eastern Canada (Ottawa, Ont.), however, where the season is more backward, oviposition has not been observed before the middle of May.

The period of emergence of those flies developing from overwintering puparia continues in accordance with the effect of the climatic conditions but it is estimated that, as a rule, eggs may be deposited from these flies during a period of two months. For instance, if eggs were laid at Agassiz, B.C., on April 10, as they were in 1915, deposition by flies of the first generation continued until approximately June 1. In late or backward springs, however, the egg-laying period would, of course be extended.

Second generation.—Taking the average of 54 days, which we think to be a fair period from egg to adult fly during the growing season, the flies of the second generation in the Lower Fraser Valley of British Columbia would commence to oviposit during the first week of June and the flies developing from maggots from these eggs would begin to appear towards the end of July. It must be remembered, however, that individuals of this generation arising from belated flies of the first generation would continue to emerge most probably until the middle of September. Thus the eggs, larvæ, puparia or adults of the second generation may occur any time between the first week of June and the middle of September under conditions prevailing at Agassiz, B.C., in 1915.

From the larvæ which emerged from eggs deposited at Agassiz on April 10, puparia were formed on May 6, and adult flies appeared about the end of

that month. Owing to the fact, however, that the egg-laying period continues approximately until June 1, in seasons such as 1914 and 1915, the emergence of the flies developing from these late deposited eggs would be about July 10. Under absolute field conditions* eggs were observed on plants on May 13 and the flies resulting from these eggs emerged on June 28, a period of 46 days from egg to adult. It must be remembered, however, as shown on page 18, that the length of the life-cycle of the insect varied from 39 to 69 days, the average of which is 54 days. In eastern Canada (Ottawa, Ont.), in 1910, numbers of flies of the first generation emerged in the laboratory from June 21 to June 27 from puparia collected in the field. The plants (cabbage and cauliflower) were transplanted on May 13 and the eggs laid about May 16. The length of the life-cycle, here, varied from 36 to 42 days, the average being 39 days. In the same year Schoene (6) found in New York State that the average individual life of the first generation was 55 days. This latter period agrees very closely

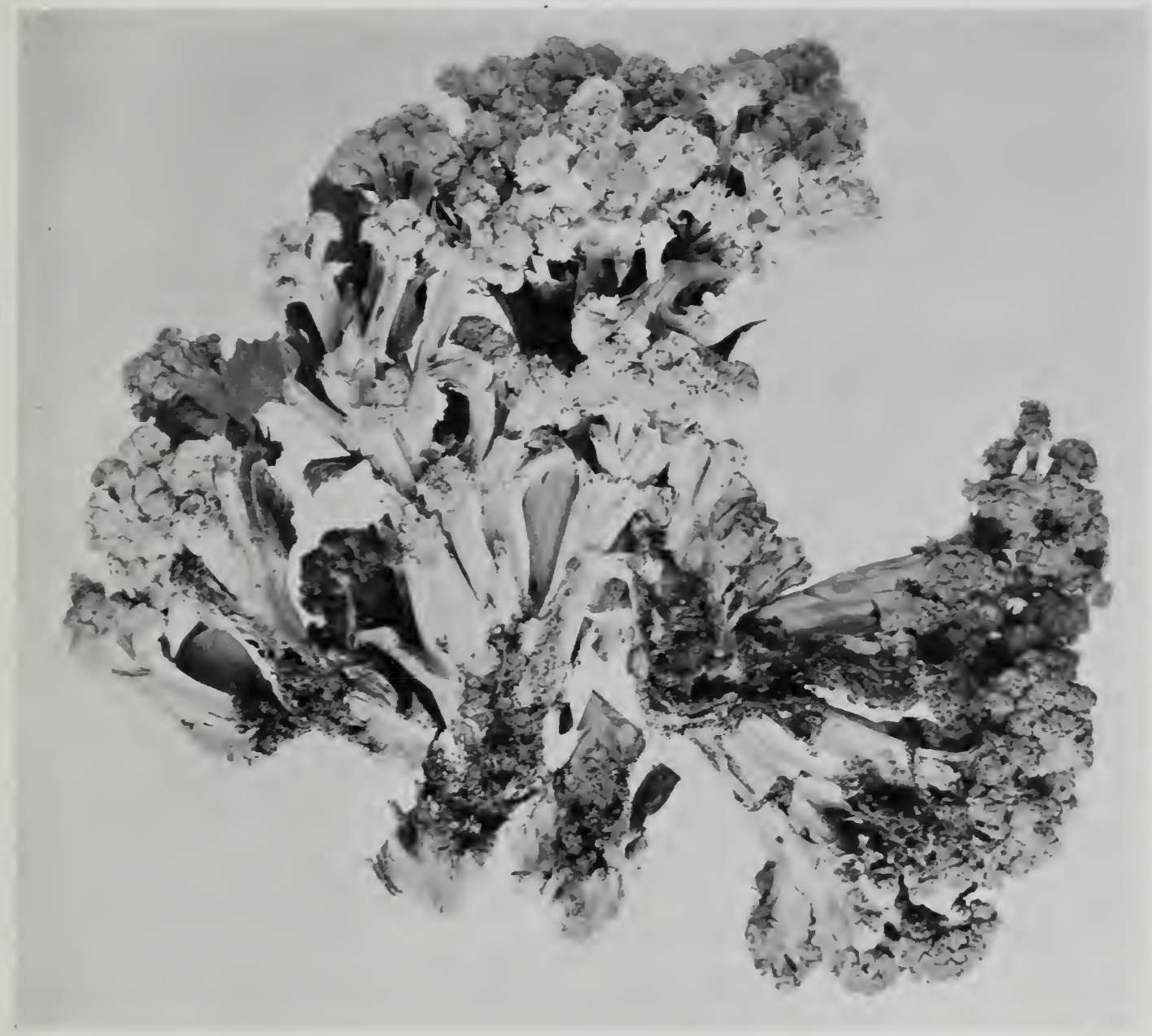

Fig. 11.—Portions of head of cauliflower injured by the Cabbage Root Maggot. (Original).

with the average life-cycle at Agassiz, B.C., as stated above. Fig. 10, drawn from conditions at Agassiz, B.C., may very well represent Ontario conditions, with the exception that egg-laying commences about one month earlier in British Columbia.

Third generation.—Using the period of 54 days, again, in which development may take place from the egg to the adult, it is possible for eggs of the third generation to be deposited at the latter part of July, in such a season as experienced

* Observations made during May and June, the method being that of inverting large lantern chimneys over cabbages and cauliflowers grown in the field.

at Agassiz, B.C., in 1915. Egg laying may continue until about the middle of September; thus maggots, puparia or adults developing from these eggs may be found through November and possibly December, as well, at Agassiz, B.C.

It should be fully realized, again, that the 54 days given as the period for development from egg to adult is arbitrary and merely taken for the sake of convenience in illustrating the overlapping generations. The actual period extends from 39 to 69 days (1915) according to our work although Schoene (6) has shown that the period in New York State may extend from 34 to 88 days (1910).

Thus any example of the insect occurring July 27, (1915), for instance, at Agassiz, B.C., may be the puparia or the adult of the first generation or eggs or maggots of the second or third generations. We have found eggs, maggots in all stages of development, and puparia, present in or near individual plants, at one and the same time.

It is probable that in some years individuals of this generation will pass the winter in the puparium stage.

Fourth generation.—There is undoubtedly in the Lower Fraser Valley of British Columbia a fourth generation of the Cabbage Root Maggot. This may be either complete or partial, according to autumn climatic conditions. In 1915, at Agassiz, B.C., eggs were laid almost continuously every day from April 10 to October 22.

As already stated, there is a variation in the dates on which the first eggs are laid in spring in the provinces of British Columbia and Ontario. Therefore, due latitude must be allowed for the commencement and termination of the various generations.

The question of hibernation is discussed on page 23 in its relation to the fourth generation and probably to the third generation also.

HABITS.

Food Plants.

The Cabbage Root Maggot, practically speaking, confines its attacks to plants of the Mustard Family or Cruciferæ, such as cabbage, cauliflower, radish, turnip and rape. In addition, however, to these crops the insect is recorded by Chittenden (7) as being injurious to celery, and Slingerland (1) records the feeding of the larvæ on the roots of Common Winter Cress (*Barbarea vulgaris*) and Hedge Mustard (*Sisymbrium officinale*), both of which are wild plants belonging to the Cruciferæ, of Mustard Family. Lintner (8) records the larvæ as mining in the leaves of beets.

In addition to the above we have one new food plant to record and also to confirm Lintner's observation of the maggot attacking the beet. The injury to beets, however, was not to the leaves as already recorded, but the maggot was found working in the roots. In 1910, when there was a serious outbreak of the Cabbage Root Maggot in British Columbia, Mr. Tom Wilson, an officer of the Branch, sent to us, at Ottawa, larvæ which were found by him working in beans in that province, and from these we reared adults which emerged between the period July 12 and July 28. On June 16 of the same year we also received from Mr. Wilson, roots of beet which he gathered near Duncan, B.C. and which were heavily infested by the maggot. From this latter material we reared adult flies in June and July. The flies from the beans and also those from beet were recently determined by Dr. J. M. Aldrich as *Phorbia brassicæ* Bouché. The occurrence of the Cabbage Root Maggot in beans and beets is most interesting but as these are the only instances known to us of this maggot attacking these crops in Canada, it would seem that this feeding habit of the maggot is unusual.

Nature of Injuries.

The only stage in the life-history of the insect which is injurious to plants is the larval or maggot stage. Injury by the Cabbage Root Maggot is largely confined to the roots of the plants it attacks, although occasionally the maggot will bore into the stem above the ground and also into the mid-ribs or fleshy leaf stalks of such plants as cabbages and cauliflowers and it has even been recorded as mining in the leaves of beets. In mid-summer we have also observed at Ottawa, Ont., conspicuous injury by the larvæ in the stems of the heads of cauliflowers. On July 22, 1912, many of the maggots were removed from a head and the photograph, which is reproduced in figure 11, taken. From our observations, it would seem that only the heads of those plants which had been attacked at the roots, as a result of which a withering of the leaves had taken place, were injured in such manner.

Fig. 12.—Root of cabbage showing Cabbage Root Maggots and their destructive work. (Original).

When the eggs of the insect hatch the young maggots immediately seek the roots, enter them and soon reduce the tissues to such an injurious extent that the leaves of the plants wilt, become discoloured, and eventually fall down. Such injury, of course, depends entirely upon the number of maggots working in the single root. Under favourable conditions of growth and when later in the season only a very few maggots are in the stem of such plants as cauliflower and cabbage, no serious injury will result. We have found in the roots of a single plant as many as 127 maggots and under such conditions, of course,

the plant is either soon killed or its marketable value greatly reduced. This statement applies particularly to early grown crops of cauliflowers, cabbages, turnips and radishes.

We have observed young maggots after hatching from eggs penetrating to the root system. Their main object is to avoid light and the quicker the penetration occurs the more likely are the young maggots to survive. Those maggots hatching from eggs deposited near the stem are attracted to the crevice formed between the stem of the plant and the soil. Many hatching from eggs deposited at a short distance from the stem of the plant on the surface of the soil, in all probability pass down through the soil until a root is reached. In laboratory experiments performed with freshly hatched maggots, carefully transferred to the surface of the soil, even when they were placed at half an inch from the stem of the plant, they burrowed downwards to the roots through some slight crevice in the soil. During such observations they were seen to stand upright with their heads inserted in a crevice, gradually working their way into the soil, until finally they became lost to view. In the laboratory, when the soil was compacted on the surface, the young maggots were unable to burrow.

Fig. 13.—Field of cabbages, near Ottawa, Ont., in which over 75 per cent. of the plants were destroyed by the Cabbage Root Maggot. (Original).

In the Ottawa district of eastern Canada the conspicuous indication of the presence of the maggot in cauliflowers and cabbages, particularly the former, is very apparent early in July, at which time the weather is very often hot and sultry. Although the maggot in Canada is present throughout the entire growing season, it is largely in May and June that the important injury to the plants is effected. In the Ottawa district entire crops, particularly of early cauliflowers and radishes, have been destroyed before the middle of June.

As mentioned above, a few maggots present in the stem would not destroy such plants as cabbages or cauliflowers, but it is different, however, in the case of radishes or garden turnips, the presence of one or two maggots being sufficient to render them unfit for the table. In the Lower Fraser Valley of British Columbia the maggot is specially injurious to plants grown in the open seed bed. In 1913, as high as 98 per cent of plants in certain beds were killed before the end of May. Radishes were also injured in the same month to a like extent. During the last two years, however, we have grown at Agassiz, B.C., crops of

radishes in open cold frames during April, practically free from maggot attack. As illustrated by the accompanying chart, egg-laying is continuous throughout the growing season and from reference to the question of egg fertility (page 11) there must be large numbers of the maggots present from early summer until late autumn. This is proven by the fact that in eastern Ontario where we have grown crops of radishes throughout the entire season larvæ have been found freely in the roots of such plants up till the middle of September and in late cabbages as late as November 9. In this latter month the larvæ have also been found in considerable numbers at Agassiz, B.C., in the roots of both turnips and cabbages.

Susceptibility of Plants.

As is well known to market gardeners, cauliflowers succumb to the attack of the maggot more readily than cabbages. This does not appear to be a result of any special choice on the part of the fly to oviposit on cauliflowers over cabbages, as our records indicate that the opposite might be the case. For instance, for a period of 17 days, between June 25 and July 11, 1915, at Agassiz B.C., 1418 eggs were deposited on six cabbage plants while 1038 eggs were laid on six cauliflower plants. In our work with this insect we have learnt to accept the vagaries of the adult in the matter of egg deposition, hence we do not claim any special preference on the part of the fly to oviposit on any special variety of plant during the height of the egg-laying period. Records have been published at various times, by those who have studied this insect in relation to crops, which were obviously based on actual results, indicating that a possibility of relief from attack might be expected in this connection. Our work, however, has shown that an apparently conclusive result of one year might be entirely reversed in the following year, and further that results might conflict even within a single season's work. This has made such a study very difficult. We consider that the supposed susceptibility of cauliflowers over cabbages is probably due to the lesser vitality of the former plants.

Seed bed trials have been conducted at Agassiz, B.C., with many different varieties of both cabbages and cauliflowers, in order to prove whether or not there existed an immune or a non-susceptible variety of plant. Some of the Red Cabbages in our experiments were less attacked than many other varieties but from a confusing amount of data, we are forced to the opinion that in all probability non-susceptible plants do not exist.

Other Causes of Injury.

In addition to the damage effected by the Cabbage Root Maggot, there are two other types of injury which annually cause much destruction and which are often confused with root maggot injury. One of these, is a damping-off fungus and the other is known as Club Root. In some years the damping-off fungus is extremely destructive in seed beds of cauliflowers and cabbages, thousands of young plants being destroyed. This disease, as its name would indicate, finds ideal conditions for development in dampish situations, and its presence in a seed bed is noticed by the falling over and dying of the young plants. The other disease, Club Root, occurs freely in eastern Canada under field conditions, and destroys cabbage, cauliflower and other cruciferous crops.

REPRODUCTION.

Oviposition.

The female fly, previous to oviposition, may be seen hovering around food plants, settling on the leaves and on the ground. When prepared to deposit

eggs the fly will move over the surface of the ground with moderate activity, in search of a suitable place to oviposit. Eggs have been observed both at Agassiz, B.C., and Ottawa, Ont., deposited on the surface of the soil within a radius of two inches from the stem of the plant. The eggs are most abundant nearer the stem and far the greatest numbers are deposited on the stems or in the crevice surrounding the stem of the plant. We have taken, during July, at Agassiz, B.C., from a single cauliflower plant, 101 eggs deposited within 24 hours. This indicates the activity of flies during the height of the mid-season oviposition period, and shows further that several females deposit eggs on the same plant in a single day. It is interesting to consider the reason why the female fly deposits her eggs so commonly on the surface of the soil around the stem of the plant. The answer doubtless lies in the fact that the shape of the leaves and their relative placing on the stem of the plant are particularly adapted to collect all available moisture in the form of rain or dew and pass it down the stem to the surface of the soil. In this manner whatever surplus moisture is left by the leaves will reach the soil within half an inch of the stem and thus affect the eggs.

Later, in the autumn, eggs have been observed deposited on the stem of the plant above ground and also on the fleshy leaf stalks, but this location for oviposition from our observations is not considered as being a very common habit even at the time of the year when the roots of the plants are old and hard.

Our notes, taken at Agassiz, B.C., in 1915, record oviposition until October 22, and almost invariably the eggs taken about this date were observed attached to the plant just below the surface of the soil in close proximity to the stem. Cold, damp weather causes the flies to cease ovipositing on plants, hence the close of the oviposition period in the Lower Fraser Valley of British Columbia occurs conjointly with the approach of the autumn rains.

The chart opposite page 24 is a representation of the egg-deposition of the flies during the season of 1915 at Agassiz, B.C. During the early part of the season (April 17 to May 20) exact records were kept on the actual daily deposition of eggs on twenty-five radish plants. The examination of these plants, as with the examination of the cauliflowers and cabbages which is mentioned later, consisted in carefully counting and removing all eggs once a day, usually about noon hour, placing them in vials, and later counter-checking them in the laboratory. In this way we believe we have obtained an exact representation of the egg-laying habits of the fly, showing not only the number of eggs laid, but the relation between egg-deposition and meteorological conditions. The number of eggs removed from the radishes between April 17 and May 20, while based on the record of twenty-five plants, has been reduced on the chart, to read on the average for one plant, for the sake of convenience. (See dotted line.)

At the time this record from radishes was being obtained the seedling cabbages, cauliflowers and brussels sprouts were growing under a cheese-cloth screen, hence the small patch of radishes from which twenty-five had been selected on which to observe oviposition, was practically the only attraction for the flies in the immediate neighbourhood.

On May 13 and 14, 1915, the transplanting of cabbages and cauliflowers (2,500) took place. Twelve cabbage plants were selected on which to observe oviposition, daily notes being taken between 4 and 6 p.m. in this instance. Observations on the plants were begun at time of transplanting and continued until September 30, by which date the plants had become too large and unwieldy to make accurate observations, in fact some were showing decay. Eggs were first observed on adjacent cabbage plants on May 16 and on the days following, but no eggs were observed on the twelve plants under observation until May 21. From this date, therefore, until September 30 daily notes were kept on the egg-deposition and the solid back line in the chart covering this period represents

SUNSHIME ——— EGG DEPOSITION
ON BASIS OF 1 PLANT.

EGG DEPOSITION OF CABBAGE MAGGOT PHORBIA BRAS

CHART ILLUSTRATING THE EGG DEPOSITION OF THE CABBAGE MAGGOT AT AGASSIZ, B.C. 1915, WITH RECORDS OF PREVAIL

the egg deposition, on a single cabbage plant, as on an average from the record of the twelve plants.

Between June 20 and July 11, six cauliflower plants were selected from different parts of the field, from which to collect data in regard to the egg-deposition on cauliflowers as compared with cabbages. The results of our findings in this connection are mentioned on page 26, and we were satisfied at the time that the cabbage plant was chosen for egg-deposition in preference to the cauliflower plant.

During the week following July 11, an occasional examination of the cauliflower plants repeatedly revealed the possibility that our records just obtained were not being sustained, and consequently, our former deductions might be incorrect. Hence the daily examination of the six cauliflower plants was again commenced on July 20 and continued from this date until October 26.

FIG. 14.—Eggs of Cabbage Root Maggot at base of stem of cabbage plant; slightly enlarged. (Original).

The dotted line covering these periods, as shown in the chart, represents the egg-deposition on a single cauliflower plant, obtained by average from a record on six plants.

It does not seem possible, however, to obtain a true record of the egg-laying habit of the fly from one kind of plant. Our records indicate clearly that we would incline towards a wrong interpretation of the autumn habits of the fly if we confined, for instance, our records to cabbages alone. From what has been stated and from an examination of the table showing numbers of eggs laid on individual plants, egg deposition on cauliflowers in September and October, would indicate marked activity on the part of the adult flies, while on cabbages the number of eggs deposited during that period was comparatively few.

The maximum and minimum temperatures, the sunshine and precipitation records, are also given in the chart, hence with the information relative to prevailing climatic conditions placed in comparison with the daily increase and decrease of the egg-deposition records we are able to observe more clearly how such conditions affect the habits of the adult fly.

The female fly does not seem to follow any regular practice in laying her eggs. On many plants these will be found laid singly, in groups of two, three or four, as illustrated in figure 14, or the eggs may be found in masses comprising as many as 15, 18, 20, and even 30.

The following table is given to represent the data obtained in the course of the egg-deposition experiments just outlined.

TABLE VI.—SHOWING ACTUAL NUMBER OF EGGS LAID ON INDIVIDUAL PLANTS, AGASSIZ, B.C., 1915.

Crop.	Number of plants examined.	Actual Number of eggs deposited.	Dates.	Average Number of eggs per plant.
Radish	25	3,437	April 17 to May 20	137·4

Cabbage transplanted May 13.	Plant Number.											
	1	2	3	4	5	6	7	8	9	10	11	12
May 21–31	.....	16	8	6	5	2	5	36	5	1	.....	2
June	156	307	277	14	234	299	231	304	158	277	456	413
July	98	153	263	250	217	610	252	120	8	118	136	252
August	50	254	164	66	8	72	73	.....	1	28	6	36
September	32	33	26	2	20	13	13	.....	.....	14	.....	2
Totals	336	763	738	338	484	996	574	460	172	438	598	705
Cauliflower transplanted May 14.												
June 20–July 11	128	251	176	263	148	224						
July 20–31	262	249	3	163	100	254						
August	127	222	120	454	303	329						
September	168	142	98	241	445	217						
October	126	63	24	122	67	26						
Totals	811	927	421	1,243	1,063	1,050						

Collective Data.

Total of 6,602 eggs were laid on twelve cabbage plants between May 21 and Sept. 30 (133 days), an average total per plant of 550·1, or an average of 4 eggs per plant per day.

Total of 5,515 eggs were laid on six cauliflower plants between June 20 and Oct. 22 (117 days), an average total per plant of 919·1, or an average of 7 eggs per day per plant.

Some most important and interesting information is to be derived from the above table. We observe that during the season of 1915, 137.4 eggs were laid around a single radish plant in the early spring. 550.1 were laid around a single cabbage plant during the summer and 919.1 eggs were laid around a single cauliflower plant between June and October.

To illustrate the degree of infestation in the plantation in which these records were obtained, it may be stated that from 215 untreated cabbages, 26 died as a result of maggot attack (12.1 per cent) and of 210 untreated cauliflowers 24 died (11.4 per cent), during the season of 1915. Many other plants of course, were infested by the maggot, but the plants survived the attack although the size of the heads was, more or less, affected.

During the course of the work involved in taking this egg-deposition record, it was observed, in the case of radishes as also in the case of the cauliflowers and cabbages, that the larger plants seemed to attract the adult flies, in consequence of which more eggs were taken from the stronger growing plants. It is impossible to say whether this is an invariable rule but, nevertheless, we have facts to support this contention so far as our work goes. For instance, cabbage plant No. 4 was checked in its growth in the seed bed, probably by a light attack of a fungous disease; at any rate it required considerable care to enable it to survive after transplanting: as a result, during May and June, it remained fully half the size of the other plants under observation. The egg-deposition on this plant, it will be noticed, was 20 eggs for the two months.

Then again, cabbage plant No. 9 was a strong growing plant in the first six weeks of its life, but early in July its leaves commenced to discolour. It was impossible that maggots were attacking the roots as all eggs laid around the plant from the day of transplanting had been removed. On examination it was found that a mole had passed directly beneath the plant, thus interfering with the root system. A check, therefore, in its growth resulted, from which apparently it never recovered. It will be noticed that 9 eggs were deposited around this plant during July, August and September. It seems apparent, therefore, that there is a relation between the size of the plant and the number of eggs deposited. The choice of the larger plants was also very clearly evidenced in the egg counts on individual radish plants.

It was noted, further, in the study of the egg-deposition, that frequently long-stemmed plants were preferred to plants with short stems, on days of bright sunshine and in fine weather. In cloudy, windy or rainy weather it was frequently observed, that the adult flies sought the shelter of the short-stemmed broad-leaved plants which afforded greater protection from the elements, for the purpose of egg-deposition. A glance at the egg-deposition chart, will show that cauliflowers attracted flies more than did the cabbages. The former, of course, is well known to have a tall, erect habit of growth.

It will be observed, therefore, from these few statements, that the question of the severity of an attack by the maggot is partially answered by a consideration of climate, size or health of the plant.

Preoviposition Period.

The preoviposition period, or in other words, the period from the time the fly emerges from the puparium until it lays its eggs upon the plants, is an important consideration in view of the fact that it has been recently demonstrated (Sanders—9) that the adult fly of a closely allied species may be destroyed by poisoning during such period. Under insectary conditions in British Columbia, flies (3 males, 6 females) which emerged from puparia on July 19 were placed in a glass breeding jar which covered a small potted cabbage plant. On July 28 all the flies were dead but on examination on the morning of July 29, 75 eggs were taken from around the stem of the plant and 8 freshly hatched maggots. The presence of the maggot indicated that eggs must have been laid at least four days previous to July 28. The preoviposition period, therefore, under such conditions was about six days. It is interesting to record here that 73.5 per cent of these eggs laid in confinement by flies emerging in the laboratory were fertile. The newly hatched maggots were immediately placed on a young cabbage plant and on August 16 a few maggots had attained the length of 3 mm. (one-eighth of an inch) and one puparium was found on August 24. In other experiments we were also successful in inducing the flies to mate in confinement and deposit eggs. Further observations, however, must be made on the preoviposition period of the fly in order to definitely determine its value as regards the control of this insect.

Hibernation.

From a study of the life-history of the insect we assume that the stage in which it hibernates in Canada is usually the puparium stage. This agrees with the published statements of other investigators. Fletcher (10) claimed that the insect also hibernated as larvæ in old stems and roots which have been left in the ground. In our observations at Ottawa, Ont., in the spring of 1904, we found in a turnip field, the crop of which had not been harvested, a single larva, which we considered to be that of *Phorbia brassicæ*, near an old root in company with many puparia of that species. Unfortunately, however, the larva was injured in collecting and after a few days it died. In 1911, on November 9, we found at Ottawa full-grown larvæ near old cabbage plants. This would bear out the supposition that the insect may hibernate in the larval form in eastern Canada. In the Ottawa district heavy frosts occur all through September, October and November. By the middle of this latter month the first temporary fall of snow has taken place, and winter in reality begins in late November or early December, when the ground freezes up.

At Agassiz, B.C., larvæ have been found in the first week of November, (1915) in sizes varying from 2 to 4 mm. long. In December (1913 and 1914) full grown larvæ were also found at this latter locality in the roots of old cabbage plants. Climatic conditions at Agassiz, B.C., differ considerably from those of eastern Canada, the rainy season commencing in autumn, and the real penetrating, cold, weather usually not beginning until about the end of December. Other students have claimed, in addition, that the insect hibernates in the adult stage, but all investigators agree that the stage in which the insect regularly hibernates is the puparium stage.

TABLE VII.—SHOWING NUMBER OF PUPARIA COLLECTED FROM THE FIELD AT AGASSIZ, B.C., IN 1915, ON THE DATES MENTIONED.

Date.	Number of puparia collected.	Number of flies emerged.	Missing or parasitized.	Sound puparia left to pass the winter.
Aug. 27	70	57	2	11
Sept. 1	75	43	6	26
" 25	65	2	.....	63
" 30	72	.....	.....	72
Totals	282	102	8	172

From this it will be seen that 61 per cent of the above puparia will pass the winter in the puparium stage, while only 36 per cent gave forth the adult flies. As previously mentioned in this bulletin no flies emerged from any of our outdoor breeding cages after September 27. In this connection we may state that at Agassiz, B.C., on September 28, 29 and 30, 1915, a field examination was made of 78 cabbage plants around which were found 124 empty pupal cases from which flies had emerged, and 96 sound and apparently healthy puparia.

The adult flies which emerge during September may be found hovering around late cabbages and cauliflowers, old cabbages, stalks, etc., in the field, and may be observed actively at work laying eggs. Egg-deposition by flies which developed in the autumn, as already stated on a previous page, may continue until October 22. Unfortunately, all of the flies reared from the September puparia and which were under observation in our outside laboratory died within three weeks, although provision had been made in the hope that

some might hibernate. While acknowledging the possibilities that under suitable conditions adult flies may winter as such, our experiments have failed to prove this fact.

THE IMPORTED ONION MAGGOT.

The Imported Onion Fly, *Hylemyia antiqua* Mg. (*Phorbia ceparum* Mg.), has for many years been a regularly-occurring pest in Canada. It is injurious in every province from Nova Scotia to British Columbia.

LIFE-HISTORY.

The Egg.

Description.—Similar in shape and appearance to the egg of the Cabbage Root Maggot Fly. Length 1.2 mm., white in colour with distinct ridges. The groove on one side is by no means so deep and conspicuous in this species as in *Phorbia brassicæ* and only extends from about one-fourth to one-half the length of the egg.

Duration of stage.—The length of the egg stage of this insect varies as in the case of the Cabbage Root Maggot Fly. The general statement has been made that the eggs hatch within a week. The actual period, however, will vary according to climatic conditions. Severin-Severin (11) recently recorded that under field conditions in Wisconsin the incubation period of eggs deposited by the first generation of flies, in early June, varied from three to four days.

Larval emergence.—We have not actually noticed any larvæ of the Imported Onion Maggot emerging from eggs, but this act is undoubtedly similar to other species of this group of flies, the young maggots of which emerge from the blunt or head end of the egg.

The Larva.

Description.—When full grown, about 10 mm. in length, white in colour, cylindrical in shape, blunt at one end, and tapering to the head, in general very similar to the Cabbage Root Maggot. The blunt end is rather rounded, not so abrupt as in the latter larva, and the fleshy tubercles at this end near the spiracles are arranged differently, as shown in figure 4 (b). In the Cabbage Root Maggot the two central tubercles are bifurcate, or two-pointed, and in the Imported Onion Maggot they are single-pointed. Near these there are also in the latter species a pair of small additional tubercles. The two black, hook-like jaws and the fan-like spiracles near the same are similar to such organs in the Cabbage Root Maggot.

Duration of stage.—The length of the larval stage ranges from two to three weeks in summer. Severin-Severin (11) have stated that in seeded onions from the previous year, the development of the maggots was often prolonged, in some instances requiring from four to five weeks.

Pupation.—When the maggot is fully fed and has reached maturity it changes to a puparium. This may take place in the soil close to the plant, or later in the season between the outer fleshy layers of the onion near the place where the larvæ have been feeding. Puparia have been found in the soil at Ottawa, Ont., at the end of August, 3 inches below the surface of the soil. In December we have found the puparia from one-half an inch to 3 inches beneath

the ground. On December 6, 1915, a number of living larvæ and puparia were found just beneath some old onion plants which had been pulled and placed on earth in an outdoor insectary, from a portion of which the screen windows had been removed. This is the only occasion on which we have found living larvæ so late in the year, and as winter had already set in, the ground being frozen hard outside, there is every reason to conclude that these larvæ would have wintered successfully and changed to puparia the following spring. In Canada we have no records of the insect hibernating in the adult form.

The Puparium.

Description.—Similar in general appearance to the puparium of the Cabbage Root Maggot figured on page 14. In length it varies from about 5 mm. to 7 mm. (rather more than one-quarter of an inch), and in colour from light to dark reddish-brown. As is the case with other similar puparia, the larval characters are retained.

Duration of stage.—At Agassiz, B.C., in 1915, the puparium stage varied in mid-summer from 14 to 26 days. In eastern Canada in the same season of the year the average length of the stage is about two weeks. The winter is passed usually in the puparium form, from which the flies do not emerge until the following spring.

The Adult.

Description of the male.—The Imported Onion Maggot Fly is slightly larger than the Cabbage Root Maggot Fly. The body of the male is of a light greenish-gray colour, the legs being darker. The body and legs bear numerous black bristles of varying lengths. On the back of the thorax are four indistinct dark coloured bands, and there is also a distinct blackish band down the centre of the abdomen. The upper portion of the femur of each hind leg lacks the conspicuous cluster of bristles so characteristic in the Cabbage Root Maggot Fly. The hind leg of the present species is shown in figure 9 (*b*) in comparison with the hind legs of the two other flies discussed in this bulletin.

Description of the female.—The general colour of the female fly is similar to that of the male. The eyes in this sex are widely separate, not close together as in the male, and the abdomen is more pointed. The bands on the thorax are very faint and in some specimens there is no band down the centre of the back of the abdomen.

Proportion of sexes.—In our breeding experiments at Ottawa, Ont., in July, 1913, the sexes reared were about evenly divided, the number of female flies being slightly in excess of the number of male flies.

DEVELOPMENT.

The development of the Imported Onion Maggot throughout the year is most probably very similar to that of the Cabbage Root Maggot. The flies which develop from overwintering puparia emerge in the spring, the exact period varying according to climatic conditions. At Ottawa, Ont., in the third week of May, in 1915, we observed the flies in numbers in an onion field. No eggs were deposited on or near the plants until June 4, when several clusters were observed. Such eggs deposited in spring develop into the first brood of maggots. In years of abundance the maggots may be found until late in the autumn, so there are probably about three broods of larvæ in a season

HABITS.

Food Plants.

The Imported Onion Maggot, under natural conditions, so far as we know, only attacks the onion plant. The various varieties are liable to infestation at any size during the growing season, but in most years it is the young plants in June which are largely destroyed.

Fig. 15.—Bulb of onion plant destroyed by Imported Onion Maggot. (Original).

Nature of Injuries.

It is only in the larval, or maggot, stage, of course, that injury to onions is effected. When the young larvæ hatch from the eggs they at once begin to work their way down within the sheaths until they reach the young forming bulb in which they feed and ultimately reduce the same, particularly the lower portions, to a rotten mass. Later in the season, when the bulb is well formed, the injury is usually confined to the lower half of the bulb, which is often entirely eaten out as shown in figure 15. We know of only one instance, at Ottawa, where the maggot was found in a stem of onion above the surface of the ground. As already mentioned, the important injury in eastern Canada in most years is specially noticed in June. When young onion plants at this time are seen to droop, the leaves appearing wilted and discoloured, it will generally be found that the maggot is responsible for such injury. Towards the end of July, and later when the bulbs are well formed, many larvæ will be found feeding together

in a single bulb. In one bulb examined at Ottawa, Ont., on July 18, 1913, there occurred 29 maggots. In another received from western Ontario on September 28, 1915, 67 larvæ, in all stages, and 12 puparia, were present.

REPRODUCTION.

Oviposition.

The Imported Onion Maggot Fly deposits its eggs on the young leaves of the plants, or later on the outside of the stem near the soil. Eggs may even be laid on the soil. The first eggs of the season of 1915 were observed at Ottawa, Ont., on June 4. On one plant 8 eggs were seen, on another 6 eggs, on another 20, and from still another 52 were taken. On other days following many other eggs were observed. Some of the eggs were one and one-quarter inches away from the plant and just under the surface of the soil. In one instance 7 eggs were found about one-eighth of an inch below the surface, close to the stem. Others were found attached to the stem and in the soil close to the stem. The eggs were most commonly found in 1915 in groups of three and four. In some years oviposition in Ontario takes place earlier than the date above mentioned. We have one record of eggs having been deposited in the beginning of the third week of May. The actual time of the beginning of egg-deposition will vary, of course, according to climatic conditions.

Preoviposition Period.

As mentioned on page 27 the preoviposition period is an important one as upon it depends the value of sprays of poisoned baits to kill the female flies before they have laid their eggs. Sanders (9) recorded the oviposition period of the Imported Onion Maggot Fly as varying from 10 to 14 days.

Hibernation.

The usual stage in which this insect passes the winter in Canada is apparently the puparium stage. The finding of living larvæ in December, at Ottawa, Ont., however, after winter had set in, indicates that the insect also hibernates in the larval form. In the United States, according to some authors, it is stated that the winter is passed in the adult stage, but so far as Canada is concerned we have no records of the flies wintering over alive.

THE SEED-CORN MAGGOT.

This insect, known scientifically as *Phorbia fusciceps* Zett., has in some seasons caused considerable damage in eastern Canada to such crops as beans, peas and corn. It is widely distributed, being found throughout the Dominion, but as yet the important injury by the maggot has only been recorded from Ontario, Quebec, and the Maritime provinces.

LIFE-HISTORY.

The life-history of the Seed-corn Maggot is not as yet fully known. The egg, which is similar to that of other anthomyiid flies, is stated to be deposited by the adult female insect upon the young seedling when it appears above ground. It is also thought that the egg may be laid on the seed itself. We have ourselves not found any of these eggs in the field, but have frequently obtained the larvæ from infested plants. As the eggs of other allied species

are deposited on the soil, it seems altogether likely that the female Seed-corn Maggot Fly would also oviposit on the soil near where the young plants are growing or where these would soon be appearing.

The Larva.

Description.—The full grown larva of this species is smaller than the Cabbage Root Maggot and the Imported Onion Maggot, the larger specimens measuring about 7 mm. in length. Like these latter larvæ it is whitish in colour, and cylindrical in shape, blunt at the caudal end and pointed at the head. The two, black, hook-like jaws are readily visible and the adjacent pair of fan-like spiracles may also be seen under a magnifying glass. The arrangement of the pointed fleshy tubercles on the caudel or blunt end is shown in figure 4 (c).

Fig. 16.—Young bean plants destroyed by the Seed-corn Maggot. (Original).

Pupation.—In 1910, when the Seed-corn Maggot was reported to us as being destructive, near Ottawa, to young beans, specimens of the maggots were secured and these pupated in the soil in breeding jars, close to the surface. We have not been able, as yet, to make any observations in the field, as regards the depths at which the larvæ hibernate, etc.

The Puparium.

Description.—Smaller than the puparium of the Cabbage Root Maggot, measuring in length about 4 to 5 mm. (about one-fifth of an inch). The colour varies from light brown to dark reddish-brown.

Duration of stage.—Larvæ collected at Ottawa, Ont., on June 23, 1910, were placed in a breeding jar and on the following day they entered the earth to pupate. The first fly emerged on July 2, 1 on July 4, 1 on July 6, 8 on July 7, 4 on July 8 and 2 on July 9. Allowing a day for the prepupal resting stage,

the pupal period thus varied from about 7 to 14 days, the average being 12 days. Jack (4) found larvæ working in wax beans on June 25; by June 28 many of them had pupated, and the flies emerged about July 10.

The Adult.

Description of the male.—Very similar in colour to the Imported Onion Maggot Fly, being of a light greenish-gray, but smaller in size, measuring from the head to the end of the abdomen, about 5 mm. (one-fifth of an inch). The body and legs bear many black bristles. The bands on the back of the thorax are indistinct, but the band down the middle of the abdomen is easily seen with the naked eye. On the tibia (the central joint) of each hind leg there is a conspicuous row of rather long bristles, as shown in figure 9 (c). By this character the fly may be at once separated from the males of the Cabbage Root Maggot and Imported Onion Maggot flies. Owing to the presence of the row of bristles on the hind tibiæ, this insect is also known as the Fringed Anthomyiian.

Description of the female.—Similar in general colour, some specimens being rather paler than the male. The eyes in the female are widely separate, and the body is pointed. The two wings, like those of similar flies, are membranous and without any markings.

Development.

The exact number of generations of the Seed-corn Maggot is not as yet known. It is supposed that there is only one generation which attacks the seedlings of such crops as corn and beans, but that there are also later generations which may feed largely on other crops and decaying vegetable matter.

HABITS.

Food Plants.

This maggot is recorded as having a wide range of food plants. In Canada it has seriously injured crops of beans, corn and peas and it is also known to infest turnips, cabbage, radish, onions, beets, seed potatoes, and hedge mustard. It is also interesting to note that the larva is known to feed upon locust eggs.

Nature of Injuries.

As in the case of the Cabbage Root Maggot and the Imported Onion Maggot, this insect is only destructive in the larval form. As previously mentioned, we have not ourselves found the eggs of this insect and do not from personal observations know the initial habits of the young, newly-hatched, larva. Eggs are no doubt laid on the soil where the seeds of such crops as corn or beans are planted. On June 22, 1910, the senior author and Mr. G. E. Sanders, Field Officer of the Branch, visited a farm near Ottawa, and found many larvæ at work in a field of pea beans. The seed had been planted about June 15, and the eggs were undoubtedly laid before the beans appeared. The maggots first attacked the cotyledons and as these were pushed above the ground and began to dry, the maggots left them, and in most plants examined, entered the stem near the roots. In some cases, however, the maggots had burrowed down through the stem from the cotyledons. The resulting injury is shown in figure 16. The important injury caused by this maggot, of course, is in the destruction of the primary shoot.

On the date mentioned larvæ were also found commonly in the seed of corn planted nearby, but no injury was done to white beans sown in the same field two days later than the pea beans. The injury to the seed of corn is well known. Figure 17 illustrates a field of corn grown near Ottawa, which was seriously infested in 1912. The interior of the corn seed is eaten by the maggots and the germ, of course, destroyed. Two and three larvæ may be frequently found feeding within a single seed. Jack (4) in recording an outbreak of the maggot in a field of golden wax beans at Chateauguay, Que., stated that about ten days after planting an examination was made for the cause of injury and it was found that nearly every bean examined was infested by from 1 or 2 to 20 or 25 larvæ; both the stems and seed leaves were attacked. Hardly a maggot could be found after July 2.

Fig. 17.—Field of corn, near Ottawa, which, in 1912, was seriously infested with the Seed-corn Maggot. (Original).

HIBERNATION.

We have no definite information as to how this insect passes the winter in Canada. In the United States it is stated to hibernate in the adult stage.

MEANS OF CONTROLLING ROOT MAGGOTS.

For many years, at Ottawa, Ont., and annually since 1910, we have conducted experiments with a large number of different insecticides, etc., in the hope of finding some reliable measure which would protect crops from the attack of root maggots. During the last three years similar work has been carried on at Agassiz, B.C. In addition to our notes, a conflicting amount of data has been published by other workers from time to time. Many vegetable growers, too, have devised ways and means to control root maggots, one year a fair degree of success being attained and in another year such control being found of no value. As a result of many experiments which we have conducted in Canada, and from reviewing the work of other investigators, chiefly in the United States, we are of the opinion that with the exception of the tarred felt paper discs for cabbages and cauliflowers very few of these hoped-for remedies are of real value. While in some seasons we have had promising results in the use of certain mixtures, several years' work with the same has not proved their worth.

The comparative abundance of these insects from year to year, the variable habits of the adult fly in regard to its choice of plant on which to oviposit and the horticultural issues, as regards soil, use of fertilizers and growth of plant, are so involved with the varying conditions of climate, such as precipitation and heat, that all one obtains, after a series of experiments on control, is an indication of virtue in one or more directions.

The following mixtures or protective measures, which we have experimented with for several years, we consider have been given sufficient test to enable us to decide upon their value:—

White hellebore, both as a decoction, in varying strengths, and dry, either alone or diluted with flour, or land plaster.
Cook carbolic wash, in varying strengths.
Kerosene emulsion.
Sand and kerosene, in varying strengths.
Sawdust and kerosene.
Carbolic acid and lime wash.
Zenoleum.
Common salt, both dry and in solution, and also diluted with sand.
Bug death.
Heavy manuring.
Glue and bran.
Carbolised lime wash.
Alkaline carbolic paste.
Sawdust and naphthaline.
Naphthaline, sand and kerosene.
Naphthaline flakes.
Naphthaline balls.
Black leaf 40.
Cliff's Manurial Insecticide.
Tobacco powder.
Soot.
Wood ashes.
Yel Ros.
Carbide slag from acetylene gas plant.
Pyrethrum insect powder, both as a decoction in varying strengths, and dry, either alone or diluted with flour.
Lime wash.
Kainit.
Sulphate of iron.
Dry lime.
Nitrate of soda.
Gas lime.
Jeye's Gardeners Friend.
Paris green and plaster.
Tarred felt paper discs.
Lime slaked with carbolic acid.
Borax in varying strengths, as a decoction and dry.
Big Dog Brand (Pearsons antiseptic).
Creolin, Pearson's.
Hycol.
Vaporite.
Sulphur.
Tanglefoot.
Abol.
Carco.
Lime sulphur (commercial).
For onions, brushing away the soil as soon as the bulb begins to form.
Cheese cloth frames and trap crops.
Washing roots in strong soap suds.

The large proportion of the above proved, from a practical standpoint, to be of little value in the control of root maggots. In fact, with the exception of those

mentioned below, we are of the opinion that the farmer or market gardener would be well advised not to make use of them as a means of controlling the ravages of these injurious insects. It can be truly claimed that the only protection to be relied upon for cabbages and cauliflowers and one which is in every way practical, is in the use of tarred felt paper discs. The initial growing of such crops in screened seed beds is recommended, together with a trap crop. The following insecticides, namely, White Hellebore, Pyrethrum Insect Powder and Carbolic Wash, have given good results but are chiefly practicable on a small or garden scale. It must be admitted, however, that even these insecticides have not in years of great abundance of the insects given by any means entire satisfaction. They have been useful for such crops as radishes, onions and garden turnips, but on account of their expense are prohibitive under acre or field conditions. The control of the Seed-corn Maggot, particularly when it is found attacking corn, peas and beans, is a difficult matter. A discussion of this will be found on page 49.

Fig. 18.—The plants in the left half of the figure were protected by tarred felt paper discs; those in the right half had no such protection and were all practically destroyed by the Cabbage Root Maggot. (After Macoun, photo by Shutt.)

One-Ply Tarred Felt Paper Discs.

As we have repeatedly demonstrated during the last 15 years, we have in the tarred felt paper disc a simple device which will give protection to cabbages and cauliflowers. This disc, about three inches in diameter, first devised by Prof. W. H. Goff, in 1889, has since been widely used by market gardeners. As an example of the success we have had with these discs it is sufficient to record that during 1915 we further demonstrated the value of these discs on a large vegetable garden near Ottawa, Ont. Discs were placed around 1,600 plants with almost perfect protection from root maggot attack, although close by in the same field and in an adjoining field, cabbages and cauliflowers were being freely destroyed. Similar satisfactory results have been obtained in other parts of Canada as well as in the United States. In 1911, at Guelph Ont., Caesar (14) applied the discs to 648 plants, 90.6 per cent of which lived.

It is important that only one-ply tarred felt paper be used in the making of these discs, not the ordinary tarred building paper. The implement for making the discs is shown at figure 19A. Some growers prefer to use a square disc with a slit running to the centre. Such a tool as here illustrated can be made by any expert blacksmith. The blades are made of steel bent in the form of a half hexagon and then taking an acute angle, reach nearly to the centre. The part making the star-shaped cut is formed from a separate piece of steel so attached to the handle as to make a close joint with the blade. The dotted lines shown at figure 19C indicate how the tool is used. The edge of the tarred felt paper should first be cut by using one edge of the tool. By thus placing the tool where the dotted lines are shown and striking the handle with a hammer, or preferably a wooden mallet, a complete hexagonal disc is cut out similar to that shown at figure 19B. The process may then be continued across the paper. If a large number of these discs are required it is advisable to mount a roll of paper

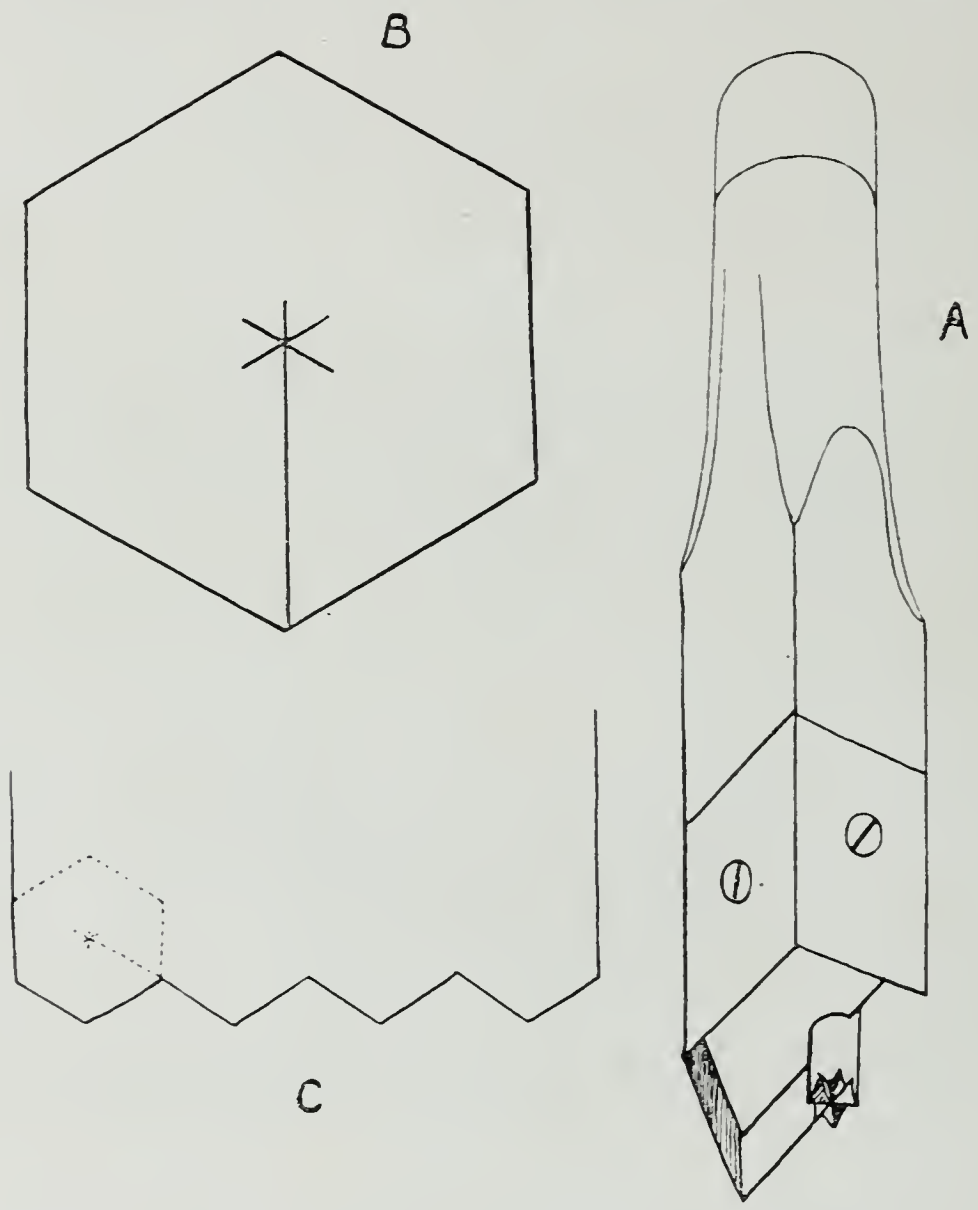

FIG. 19.—(a), Tool used for cutting tarred felt paper discs, one-third size; (b) disc about one-half size; (c) showing how the tool is used, the dotted line indicates the position of the edge of tool. (After Goff).

as shown at figure 20. One yard of tarred felt paper is sufficient to make about 200 discs, and the time required for the making of such is about three-quarters of an hour. The cost, therefore, is very slight.

It is very important that the discs be placed around the cabbages and cauliflowers as soon as possible after they are set out in the field. One man should walk behind the planter and do this work on the same day the plants are put out, otherwise, if any delay occurs, even of a few hours, the fly of the Cabbage Root Maggot may visit the plants and deposit eggs on the stems or in the soil nearby, from which maggots would hatch. If the land is well cultivated before the plants are set out, it is wise to delay further cultivation for a couple of weeks. If this is done the discs will not become covered with earth and their value will be retained. If, however, it is found necessary to cultivate it is advisable, if at all possible, to go

over the plants and remove the earth from the discs by means of a small broom or whisk. The discs, with ordinary care, may be quickly and properly placed around the stems of the plants. One side of the disc is raised sufficiently to allow the parts of the star at the end of the slit to point upwards and thus fit close to the stem. The whole disc is then pressed down firmly so that it will rest evenly on the ground. Fig. 21 shows a disc placed correctly around a plant and the same figure at *b* illustrates a carelessly placed disc. The latter is useless

FIG. 20.—Simple method of mounting a roll of tarred felt paper, when a large number of discs are required. (From 14th Report of the State Entomologist of Connecticut).

as a protection. If the soil is inclined to be rough or lumpy it is advisable to roll it before planting the seedlings in order that the discs may lie flat on the ground. As mentioned on another page, the beds in which the seedlings are grown may become infested and if this is found to be the case all earth should be removed from the plants immediately before they are set in the field and the discs adjusted.

FIG. 21.—A, showing properly placed disc; B, carele sly placed disc. (After Hewitt).

CHEESE CLOTH FRAMES.

The use of ordinary cheese cloth as a screen against the attacks of insects injurious to the young cabbage and cauliflower plants, such as root maggots, flea beetles, etc., is considered to be a preventive of undoubted value. Further,

by this method, sound, healthy and well-grown plants will be taken from the seed bed for transplanting to the permanent field.

In 1903, Macoun (15) conducted experiments at the Central Experimental Farm, Ottawa, Ont., on the value of a cheesecloth enclosure in its relation to the growing of vegetables and this work was continued by him in 1904. The idea originated from some work that had been carried on, in the United States, for three or four years previous to 1903, in shading different crops but mainly tobacco. Fletcher, (16) in commenting upon Macoun's work during the season of 1903, stated that the use of cheese cloth enclosures in producing vegetables of high quality had "an important entomological bearing."

The frame used in Macoun's experiment stood six feet high from the ground, and was made of 2 x 4-inch scantling. Such a high frame is not now, of course, considered practical or advisable to prevent attack by root maggots. In 1904, Fletcher (17) records the use of a much smaller cheese cloth frame, namely, one measuring 8 x 2 x 2 feet, which was applicable in smaller gardens and the frame of which could be used for several years. Such a screen of course was intended to protect plants after they had been set out, or under which to grow radishes.

FIG. 22.—Cheese cloth screen to protect plants from root maggot attack. (Original).

Schoene (18) in 1908, advised that tests be made by growers in New York State on the value of screening seed beds. The frame suggested consisted of 12-inch boards held upright by stakes. Heavy wire running the length of the bed was to be employed to support the cheesecloth and prevent it from sagging. Later, in 1911, the same writer (19) followed his earlier suggestions by a further statement on the value of cheese cloth frames for protecting seed beds.

On the Experimental Farm at Agassiz, in the Lower Fraser Valley of British Columbia, we have been using for the past three years a cheesecloth screen, 8 feet x 12 feet x 20 inches high (see fig. 22). Such a light wooden frame may, of course, be used for a number of years, with a renewal of the cheesecloth each year. Light cross braces of wood support the cheese cloth from sagging, and the whole structure is sufficiently light to enable one man to raise one side by himself and place supports from the ground to the edge of the frame to prop it up, thus enabling him to work among the plants, if such a crop as radishes were being grown. A portable screen of this nature may be used continuously throughout the season for successive crops of radishes. We have used such screens for

protecting radishes in the early spring, with seedling cabbages, cauliflowers and brussel sprouts growing in the same enclosure, with absolute success, and after the latter plants have been removed to the permanent plantations, the whole screened area may be used for further crops of radishes. In order to harden cabbages and cauliflowers grown in screened seed beds the screens, which must

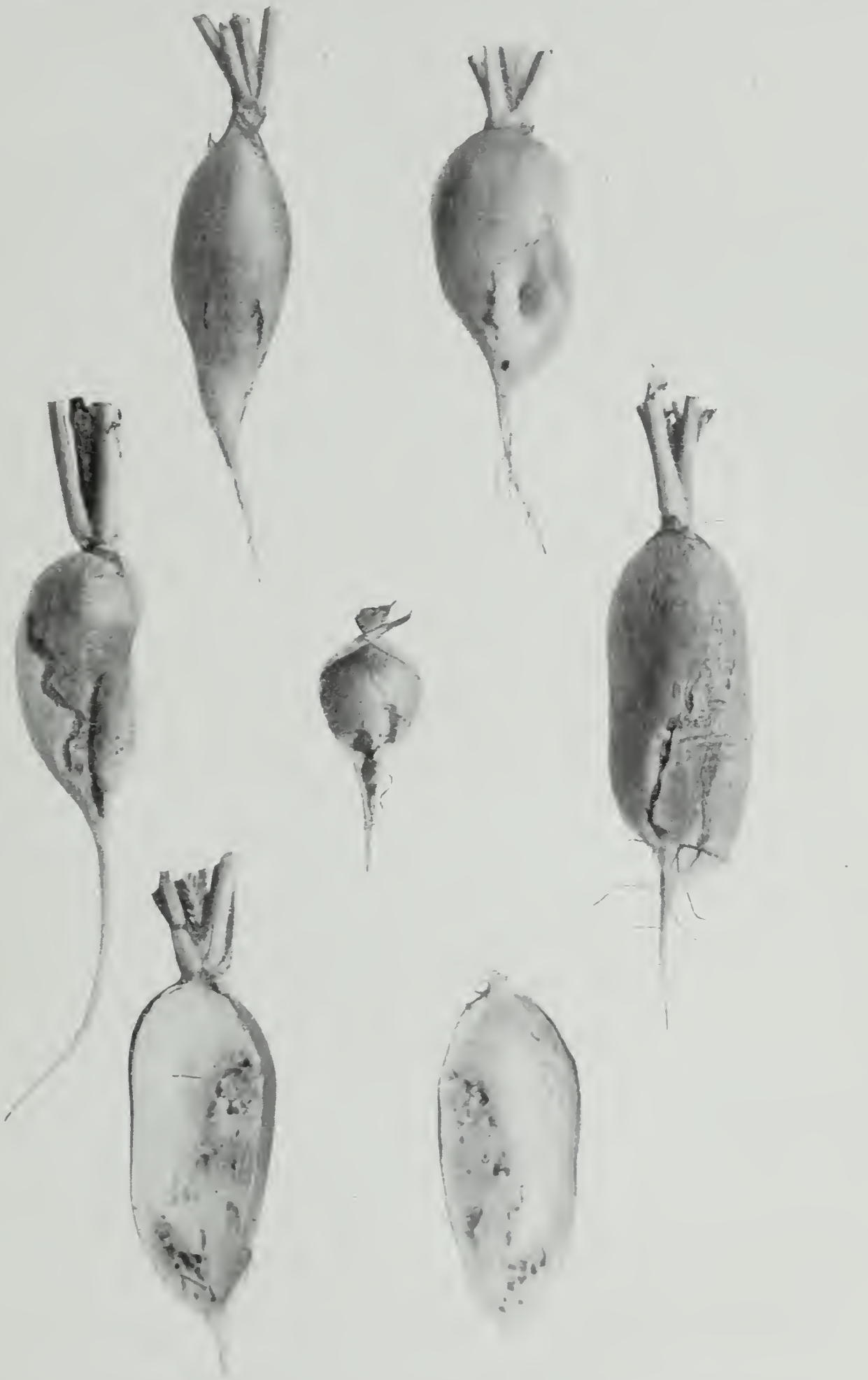

FIG. 23.—Radishes destroyed by the Cabbage Root Maggot. (Original).

not be finally removed until about a week before transplanting, should be gradually raised each day, especially in hot sunny weather, although no harm has been observed at Agassiz, B.C., when transplanting takes place in a dull moist spell of weather direct from the screened beds. Care must be taken to guard against fungous diseases in the seed bed, the most serious being a "damping off" fungus. To offset fungous diseases it is well to use a different location each year for the

seed bed. Well-drained, rich soil must be chosen and very often a coating of lime or clean sand to the surface of the bed will be advantageous.

Trap Crops.

The screening of seed beds, as mentioned above is important and this protection has a direct bearing on the value of trap crops. It has been observed by Slingerland (1) and by others who have studied the habits of the Cabbage Root Maggot, and it may be seen by the chart opposite page 24, based on our work at Agassiz, B.C., that the first generation of the insect is clearly defined. This means that in some years, at any rate, there is a short lapse of time between the oviposition by the flies of the first and the second generations. In 1915, the period during which few eggs were laid, was comparatively long, namely from about May 20 until about June 7. In years when oviposition by flies of the first generation is delayed by unfavourable climatic conditions, the separation between the first and second generations would not be so marked. However, in any year there would apparently be a drop in the curve on an egg-deposition chart just previous to the emergence of flies from first generation eggs. This is an important point as it indicates the advisability of sowing a small patch of some crop, such as radishes, to act as a trap upon which the eggs of this first generation could be laid. Provided the seed beds containing cabbage, cauliflower and early table radish plants, are properly screened during April, many flies emerging from the soil in the vicinity will be attracted to the trap crop of radishes. Reference to the table on page 26 will disclose the fact that upon each radish plant of a trap crop grown during 1915, 137 eggs were deposited. Transplanting of cabbages and cauliflowers took place at Agassiz. B.C., between May 20 and 26 in 1913, on May 25, 1914, and May 13 and 14, 1915, and it will be seen that these dates coincide very favourably with the termination of the first generation oviposition period of 1915.

Such a trap crop as radishes upon which the flies will be attracted to deposit their eggs should be removed and destroyed either by burning or burying at least a foot deep. This should be done about three weeks from the time the radish seed is planted. In this way, as a study of the egg and larval stages of the insect would show, all the maggots would be destroyed before they transform to the puparium stage. Thus, according to the earliness of the season and the subsequent hastening of the development of the adult flies of the first generation, would such a trap crop be proportionately effectual.

During the summer we have, at Agassiz, B.C., grown radishes in the open field between rows of cabbages and cauliflowers, in the hope that the radish plants would attract the flies for egg-deposition. Our experiments, however, did not indicate that such a trap crop, grown in the field would be of any special value.

Autumn Planting.

Many growers in the Lower Fraser Valley of British Columbia seed cabbages and cauliflowers in August and September and transplant the seedlings to the open field in September and October. This system, which is entirely successful from a horticultural standpoint in most years, is pursued with two objects in view, (1) to ensure earliness the following year and (2) to enable plants to become well established so that they will be better able to withstand attack by the maggot in the spring. Experience with the growing of cabbages and cauliflowers under this plan has shown us that both good and poor success may be expected. Success or failure depends entirely on the early spring temperature in relation to the emergence of the insect from winter quarters and also on the number of available plants in the spring on which the flies, as they emerge, are able to deposit eggs. I such a spring as we experienced in 1915, for instance, which was not out of the ordinary in the Lower Fraser Valley, when the adult flies were at

work depositing eggs in early April, it stands to reason that unless a number of plants are available to attract the flies, they will deposit eggs mainly on autumn grown plants. Further, small gardens are liable to suffer more in this respect as the area is more concentrated and fewer plants are concerned. In order to offset the possibilities of loss in the spring to autumn-grown cabbages and cauliflowers, farmers and vegetable gardeners are advised to seed radishes, as trap crops, as mentioned on page 42, so that the attractive area for egg-laying by the female flies will be enlarged.

White Hellebore.

This insecticide, which is a powder ground from the roots of the plant known as Hellebore has been experimented with for many years at Ottawa, as a remedy for root maggots, both in the dry form and as a decoction. Its value in this connection was recommended to the late Dr. James Fletcher by a successful Ottawa gardener about the year 1888. Recently, however, we have made a closer study of the value of Hellebore as a control measure for these insects, and in garden practice have, protected to an appreciable degree, such crops as radishes onions and table turnips. Used in the dry form the powder is simply dusted along the rows of radishes or onions, the first application being made when the plants appear above ground and two further applications a week apart. As a decoction, the mixture is applied by means of an ordinary watering can with a small spout, three treatments being made once a week from the time the plants show through the soil. In our garden experiments we have used Hellebore in such strengths as 1 oz., 2 oz., 3 oz., and 4 oz. to the gallon of water. A strength of 2 ozs., to the gallon of water has given on the whole as good results as decoctions of 3 ozs. and 4 ozs. Such increased strengths are unnecessary and, of course, materially add to the cost of the applications. If the Hellebore is first steeped in a small quantity of warm water it will mix better with the required amount of liquid necessary to treat the plants. The Hellebore decoction is more quickly applied than the dry powder, and, of course, the operation is much easier. The former too, is much cheaper.

Fletcher (20) in 1890 with one assistant, treated 1,200 cabbages about July 1. "One person carried a 3-gallon pail full of water, in which 2 ozs. of White Hellebore had been steeped, and an ordinary greenhouse syringe; the other placing the left hand beneath the cabbage, palm downwards, with two fingers on each side of stem, drew away the surface soil from the root of the cabbage and at the same time, with the right hand, pulled the head a little over, so as to expose the roots. About half a tea-cupful of the liquid was then syringed forcibly around the roots and the earth was quickly pushed up again around the stem. The result of the treatment was that only 1 per cent of the cabbages was lost. There is no doubt that the forcible syringing of the liquid removed the maggots to some distance from the roots: but by actual experiment it was found that the White Hellebore killed them also. Furthermore, the moisture was of great assistance to the cabbage in recovering from the injury."

Pyrethrum Insect Powder.

Results obtained from a number of years' experiments under garden conditions with this insecticide, which is made from the heads of plants known as Pyrethrum, are in general similar to those obtained from the use of White Hellebore. Varying strengths were used from 1 to 4 ozs. to the gallon of water, the strength of 2 ozs. to the gallon giving as good results as 3 ozs. or 4 ozs. Three applications were made with a watering can, with an interval of one week apart, the first treatment being applied when the radishes first appeared above ground. It is, of course, important that the insect powder be absolutely fresh and it should be delivered in sealed tins. In addition to the decoctions, we have also

used it in the powdered form alone and with a dry diluent such as cheap flour, the proportion being one part of the Insect Powder to four parts of flour. The decoction, of course, is the cheaper method of application.

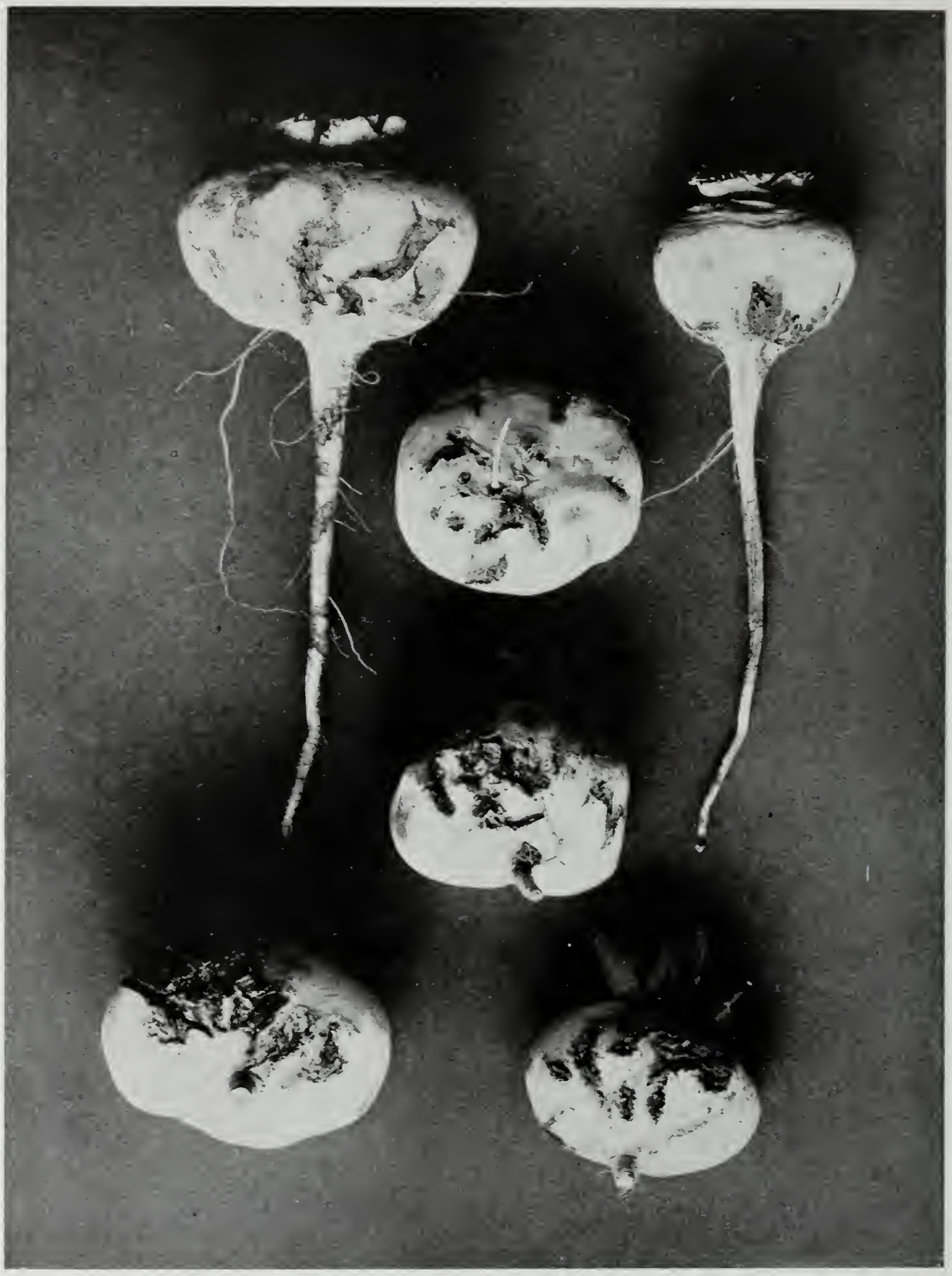

Fig. 24.—Garden turnips destroyed by the Cabbage Root Maggot. (Original).

Cook Carbolic Wash.

This wash has also been repeatedly tested at Ottawa, Ont., and more recently at Agassiz, B.C. It is made by dissolving one pound of hard soap, or one-quart of soft soap, in one gallon of boiling water and afterwards adding one pint of crude carbolic acid, and boiling the whole together for five minutes. This makes a stock solution. When required for use the emulsion should be used in the proportion of one part to thirty-five parts of water. The diluted wash

may then be sprayed directly upon the growing plants, or applied around the roots by means of a watering can. It is important that the mixture be applied as soon as the plants appear above ground and repeated once a week for several weeks, in the case of radishes two or three applications or until they are ready for the table and with onions and turnips until they are strong enough to resist attack.

On June 17, 1913, at Ottawa a number of cabbages which were seen to be seriously infested were examined and larvæ of the Cabbage Root Maggot Fly in several stages were noticed at work, as well as clusters of eggs on the stems. The earth around the tops of the stems of 10 rows of these plants was removed and about a cupful of the carbolic wash in the above strength was poured from a watering can. Two further applications were made a week apart, and as a result of these treatments, the plants recovered from the initial attack and the resultant crop was profitable.

CONTROL OF ROOT MAGGOTS UNDER FIELD CONDITIONS.

Turnips.

Field turnips, grown for cattle feed, are often attacked and seriously injured by root maggots. On the Experimental Farm, Agassiz, B.C., through the courtesy of the Superintendent, Mr. P. H. Moore, we were enabled to carry on an experiment on the control of root maggots under practical field conditions, during 1913. Approximately 1½ acres were planted to field turnips in that year and in order not to conflict with Mr. Moore's variety test experiments it was only possible to use two mixtures, namely, Carbolic Wash and Kerosene Emulsion. Both mixtures were applied on the occasions with an ordinary watering can with its spout plugged by a rubber cork through which a half-inch glass tube had been placed. The last treatment, on June 25, was applied by a 40-gallon barrel spray pump arranged on a one horse cart.

TABLE VIII.—SHOWING TIME AND LABOUR REQUIRED IN ABOVE EXPERIMENT.

Date treated.	Size of plant in inches.	Time expended in operation of mixing and applying.	Labour required.
May 23	½	7 hours.	1 man.
May 29	1—2	3 hours.	1 man.
June 11	5—6	6½ hours.	1 man.
June 25	.....	3 hours.	1 man. 1 horse.

The field was thinned on June 10. On the close of the experiment in the autumn the turnips were weighed with the results shown in the following table.

TABLE IX.—SHOWING WEIGHTS OF TURNIPS HARVESTED REDUCED TO READ ON THE BASIS OF 87 FEET OF ROW.

Field Turnip Variety Name.	Total Weights per 87 Feet of Row.		
	Carbolic Wash.	Kerosene Emulsion.	Check (No treatment).
	lb.	lb.	lb.
Magnum Bonum	564½	506	520
Good Luck	735½	679½	695
Bangholm	665	554	644
Mammoth Clyde	463½	361½	.....
Hartley's Bronze Top	528	472½	.....
Jumbo	600	435	446
Halewood's Bronze Top	547½	367	.....
Perfection	494	433	.....
Lapland	557	523	540
Hall's Westbury	611	507	548
	5,766	4,838½	.....

This gives a difference of 927½ lbs. on the basis of 87 feet of row in favour of the Carbolic Wash, a point which is significant, as in every instance the rows treated with Carbolic Wash were heavier in yield than those treated with Kerosene Emulsion. Outside rows were eliminated from the test as it was thought they would have an unfair advantage over the other rows, thus, in the above table, some check row counts were not kept.

On the estimate of the six varieties on which satisfactory checks were kept the following record is made:—

Carbolic Wash, average of	87	feet of	row.....	622 lbs.
Kerosene Emulsion	„	„	.....	534 “
Check	„	„	.....	565.5 “

The above estimate approximately only gives a cash value of about $2.00 in favour of treatment, exclusive of its cost, consequently it is doubtful whether such treatments will prove practical to control root maggots when these occur in fields of turnips. The following table gathered from the same series of experiments in 1913, on the relative value of heavy versus light seeding of field turnips, is more indicative of practical value.

TABLE X.—RESULT OF EXAMINATIONS MADE AT VARIOUS TIMES IN MAY, 1913, FOR THE EGGS OF THE CABBAGE ROOT MAGGOT FLY IN ROWS OF TURNIPS, BOTH THICKLY AND THINLY SEEDED.

Number of Plants to lineal foot of row.	Average Number of eggs counted.	Average Number of eggs per plant.
13	72	5·53
20	54	2·7
46	143	3·19
72	52	0·72

From the fore-going table we find there are indications that fewer eggs are laid per plant in thickly seeded rows, consequently, it is considered advisable to seed heavily in a district where turnips frequently suffer from maggot attack.

CABBAGES AND CAULIFLOWERS.

As we have stated on page 36 we are of the opinion that the only practical and efficient method of controlling root maggots in cabbages and cauliflowers

FIG. 25.—Roots of cabbages, showing destructive work of the Cabbage Root Maggot. (Original).

under field conditions at the present time is in the use of a cheese cloth protection for the seedlings and the employment of tarred felt paper discs at time of transplanting.

ONIONS.

The control of the Imported Onion Maggot, which confines its attack to the onion plant, has proved a difficult problem under field conditions. Such insecticides as Hellebore, Insect Powder and the Carbolic Wash, which have been of value in garden practice, are prohibitive for field conditions owing to their expense and cost of application, and in seasons of great abundance of the insect it is doubtful if the results would be satisfactory. The most promising experi-

ments which have been recently conducted to control the Imported Onion Maggot are those in which a poisoned bait spray was used to destroy the adult flies before they laid their eggs upon the plant. As has been mentioned on page 27 there is a preoviposition period of several days during which time the flies might with practical advantage be attracted to a sweetened poisoned bait. Sanders (9) stated that from a careful study of the life-history of the Onion Maggot, it was determined that a period varying from 10 to 14 days lapsed after the emergence of the adult female before fertile eggs were deposited. The same investigator used a spray composed of five grams of sodium arsenite dissolved in a gallon of boiling water into which was thoroughly mixed one pint of New Orleans molasses. The bait was applied as a coarse spray of large drops once a week in strips across the onion field throughout the summer. The results indicated almost perfect control at a cost not to exceed 50 to 75 cents per acre for the summer treatment.

Later (21) the same writer stated that "an ordinary hand syringe, or a whisk broom dipped into a bucket of spray and shaken about on each side of the operator will apply the liquor satisfactorily. It is possible in this manner to treat a strip thirty feet broad on each trip across the onion field. In actual practice it has been found that a field may be treated in checkerboard fashion, or in alternate strips, leaving an untreated strip of a width similar to the treated areas, since the flies are strongly attracted to the poison bait spray when freshly applied. The frequency of treatment is most important. During fair weather the application of this poison bait once a week regularly is sufficient, but in rainy weather it is desirable to apply it at least twice a week, especially if a shower follows the application. It is urged that the poison bait spray be also applied to weeds or other vegetation adjoining the onion fields, to poison any individual flies that may be resting at these locations. Several onion growers in Wisconsin tried out this poison bait spray under actual field conditions last summer, and reported that they harvested almost perfect stands of onions, the best crops they had grown in fifteen years or more."

Professor Sanders has recently informed us in correspondence that "During the summer of 1915, Mr. Neale F. Howard, a graduate student at the Wisconsin College of Agriculture, carried on experiments on the control of root maggots, particularly the Onion Maggot, on the Smith Brothers' truck farm at Green Bay, Wisconsin, co-operating with the U. S. Bureau of Entomology. The summer of 1915 was decidedly abnormal from the standpoint of weather, on account of the excessive rain and unusual cold. Naturally, the results obtained by the use of the poison bait spray for controlling the Onion Maggot were not so successful as in previous trials, but Mr. Howard developed another method which has proved very satisfactory and has yielded good results. By placing 15 or 20 small pans per acre about the onion field and filling them partially full with the poison bait mixture, quite satisfactory results were secured in controlling the Onion Maggot in spite of the unusual season. It may develop in further trials that this method will be even more satisfactory than any spray method in ordinary seasons, particularly for the first brood of maggots, since at this time very little plant material is above ground to which drops of spray mixture may adhere. Later on in the season, for the second and third broods, the onions have grown sufficiently to retain a considerable portion of the spray material."

With regard to the method of using the poisoned bait in cans, we would suggest that a small quantity of excelsior packing be placed in each tin which would enable the flies to more readily gain access to the mixture.

Severin, H. H. P. (22) also indicates the attractiveness of poisoned molasses for the adult flies. In July, 1913, in the sprayed portion of the onion field numerous flies were seen on the leaves feeding on a mixture similar to the above, namely: molasses, ¼ pint; sodium arsenite (dissolved in boiling water) ¼ oz.; water, 1 gallon. This spray, which was used against the second genera-

tion, gave promising results, four applications having been made once a week from July 10. As yet, in Canada, no experiments with poisoned baits to control root maggots have been conducted under field conditions, but as such baits give promise of value, they will, of course, be tested in the near future when suitable conditions occur.

CORN, BEANS AND PEAS.

The root maggot which causes the chief damage to these crops is the Seed-corn Maggot. Fortunately, it is not a regularly-occurring pest. For this reason, it is extremely difficult for the farmer or market gardener to anticipate the presence of the insect in his fields. The recommendation has been made by other investigators to use the Carbolic Wash in the control of this insect, but as the maggots do their chief injury to the seeds and young seedlings of the crops mentioned, namely, corn, beans and peas, it does not seem to us that applications of such a wash would be of any value. The important preventives, we think, would be to sow such seeds not deeper than one or two inches in good season and in well prepared soil. When seed is planted during a period of cold and damp weather decay to the seeds, of course, is liable to set in and the conditions possibly rendered more attractive to the adult flies for egg-deposition.

Cultural Control.

ROTATION OF CROPS.

The value of growing crops in different situations each year is of course undoubted. We have performed no experiments on the range of the flight of root maggot flies, but there is plenty of evidence to support the conclusion that it is extremely difficult to obtain maggot-free crops in districts previously considered free but within say half-a-mile of an infested area. The mere facts that the Cabbage Root Maggot will feed on cruciferous weeds and that adults are undoubtedly carried by the wind, largely affect the value of crop rotation as a control measure for root maggots. Any practice, of course, that may restrict the spread of the flies is advisable, hence crop rotation, being strictly in accord with the best agricultural practices, is recommended.

HEAVY MANURING.

It has been recorded frequently that stable manure attracts female flies of the family Anthomyidæ, to which the root maggots belong. Hewitt (23) has stated that *Anthomyia radicum* Mg., which is closely related to the Cabbage Root Maggot, *Phorbia brassicæ* Bouché, "is attracted to and deposits her eggs very freely upon horse manure, in which the larvæ develop in a comparatively short time." Reference, by the same writer, is also made to Theobold's Report on Economic Zoology for the year ending April 1, 1907,in which some evidence tends to show that the presence of manure is beneficial to the larvæ of the Cabbage Root Maggot. We have no data ourselves to offer in this connection. Other investigators in North America have indicated that stable manure is apt to attract the flies of our destructive root maggots for the purpose of egg-laying. It would, therefore, seem advisable, in spring, to avoid the use of such fertilizer, as much as possible, in fields which are known to be infested by these insects.

OTHER HORTICULTURAL PRACTICES.

It is not the purpose of this bulletin to detail at length the horticultural issues involved in the control of root maggots. The correct preparation of the soil for such crops as cabbages, cauliflowers, radishes, onions, corn, etc., the proper fertilization and other necessary practices have been made the subjects of many bulletins. Suffice it to say, although it has been shown that the larger plants appear to be more often chosen for egg deposition, being stronger and having more vitality, it is, of course, understood that they are better able to withstand attack. It is, therefore, advisable to pay due regard to soil preparation and crop fertilization.

During 1915, and in connection with our study of the Cabbage Root Maggot and its control at Agassiz, B.C., a series of cultural experiments on cabbage and cauliflowers were also performed which, while they were not very extensive in outline, are recorded here for their worth. The experiments took the form of the following: (1) Washed roots, in which roots were placed under running water so that every particle of soil was removed at the time of transplanting; (2) Balled roots, in which at time of transplanting, the roots were carefully removed with soil with a minimum of disturbance to the roots; (3) Deep planting in which the plants were set so deep that the leaf stalks of the lowest leaves were partly buried in soil; (4) Shallow planting, in which the roots were only just covered but carefully set; (5) Seed bed thinning, in which plants were thinned by hoeing in the seed bed, those plants left being undisturbed; (6) Level culture, in which the soil was not drawn up to the plants during the summer; (7) Hilled plants, in which the soil was mounded around the plants in June; (8) Caging after transplanting, in which small wire cages were placed over each plant for a month after transplanting. These cages were made by dividing one yard of ordinary mosquito-wire into six equal parts and each part being rolled and pinned on the side and on the top.

The results in weights at harvest were as follows, reduced to an equal basis of 15 plants to each test:—

(1) Washed roots	34.50 lbs.
(2) Balled roots	60.75 lbs.
(3) Deep planted	23.00 lbs.
(4) Shallow planted	42.75 lbs.
(5) Seed bed thinning	47.00 lbs.
(6) Level culture	39.00 lbs.
(7) Hilled or mounded	40.09 lbs.
(8) Caging after transplanting	57.00 lbs.

The plants constituting the series numbered 3 to 8 were removed from the seed bed in the ordinary way, no special care being taken to protect the roots. No. 2 indicates the importance of careful transplanting.

TREATMENT OF LAND AFTER HARVEST.

Obviously, this is an important consideration in the control of root-infesting insects, because on the basis of the efficiency of measures applied in the autumn very often will affect the degree of early spring infestation.

Autumn cultivation, ploughing and the destruction of old stumps and other remnants of crops, are methods of control which have been recommended for root maggots at various times, from many sources. There is little question that these recommendations may be supported by our knowledge of the life-history of the flies. It has been seen, for instance, especially in the life-history of the Cabbage Root Maggot Fly, at Agassiz, B.C., that egg laying by female flies may

be continuous on old stumps of cauliflowers and cabbages, throughout the summer until late in October, and that maggots may be frequently found actively at work both at Agassiz, B.C., and at Ottawa, Ont., until November and December. It is desirable, therefore, that the old stumps of the summer's crop be properly disposed of, so as to destroy any immature maggots present. Too much reliance, however, must not be placed on such practice, as an efficient control method, as there is no doubt that the great majority of maggots have formed their puparia by the middle of September and having done so, would remain in the soil even if the old stumps were pulled and destroyed.

We have observed on page 14 that puparia buried nine inches deep are able to work their way to the surface, hence the value of deep ploughing as a practical control is doubtful. There is a decided lack of evidence on the effect of ploughing, either deep or shallow, in its relation to the control of root maggots.

When crops are being cultivated throughout the season it is, of course, always a good practice to remove plants which have been seriously injured by root maggots. In the case of cabbages, cauliflowers and onions, which readily show fatal injury, care should be exercised in pulling these up, so as to disturb as little as possible the maggots which may be present in the plants. These latter, if time permits, should be gathered up at once and destroyed in some way.

Natural Control.

CLIMATE.

The control of root maggots by meteorological conditions, such as the effect of relative degrees of heat, cold or drought, extent of precipitation of snow or rain, or whether plantations are exposed to winds or not, are obviously matters largely beyond the control of the vegetable gardener. That such meteorological conditions govern the severity of attacks by root maggots and play an important part in the natural control of these insects, are undoubted.

We have noted in this bulletin how drought affects the fertility of the eggs. It is true that most of our observations on these points have been made under laboratory conditions, yet we do not doubt that similar effects are brought about under field conditions. In the study of the Cabbage Root Maggot, in particular, in different sections of Canada where varied conditions of climate are experienced, it is noted that the insect is much less serious in arid sections and *vice-versa* much more injurious in those places where atmospheric conditions are more humid and where rainfall is more frequent.

From this, therefore, it is assumed that moist conditions favour the development of the insect. It has been observed, however, that a cold, wet, spring retards the appearance of the adult fly and checks development in the early stages of the maggot. Further, the matter of egg-deposition in autumn and the emergence of adults from puparia are hindered by and dependent upon climatic conditions. Indeed, the whole question of the development of the fly in British Columbia in the autumn and the length of the period of activity is entirely dependent upon the approach of the autumn showers. Consequently, the most suitable arrangements for the development of the Cabbage Root Maggot, for instance, will combine a moderate amount of rainfall and sunshine. It is desirable that this should be realized by the vegetable grower, as it will partly assist him in determining the reason why in some years he will suffer from the pest more than in others years.

PARASITIC INSECTS.

Although there are several important parasites of root maggots, which some years assist considerably in their control, the farmer and market gardener

should not rely on the abundance of such beneficial insects in his fields in the hope that artificial remedial measures will not be necessary.

The following parasites have been reared in Canada:—

Baryodma ontarionis Casey.—This useful parasite, which was recently described as a new species by Col. Thomas L. Casey,* is apparently the staphylinid which has long been known in eastern Canada as an enemy of the Cabbage Root Maggot. In the Ottawa district of eastern Ontario it has been found many seasons in our fields of cauliflowers, cabbages and radishes, infested with the Cabbage Root Maggot. In 1901, Fletcher, (12) under the name of *Aleochara nitida* stated that the insect occurred in large numbers on some sandy lands at Ottawa, and by the end of the season hardly any root maggots, or their puparia, could be found in a place where they were usually very numerous. This indicates the usefulness of this very active parasite. In 1910 we reared, at

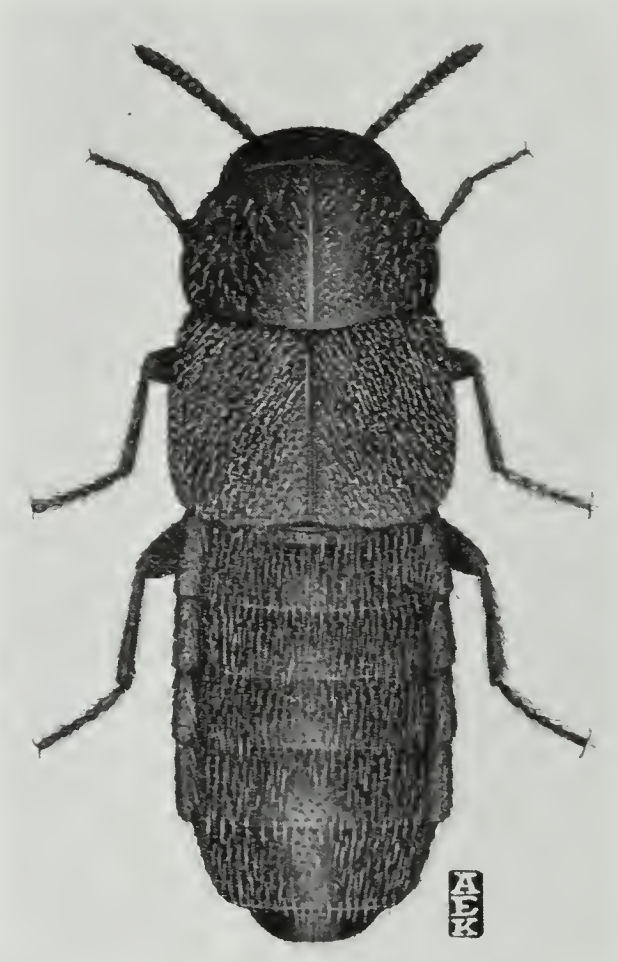

FIG. 26.—*Baryodma ontarionis* Casey, a staphylinid parasite of the Cabbage Root Maggot. (Original).

Ottawa, from Cabbage Root Maggot puparia collected on June 21, many specimens of this small staphylinid, the beetles appearing from July 6 to July 12. From puparia collected on August 15, of the same year, beetles emerged from August 21 to September 14. To illustrate the importance of this parasite in assisting to control the Cabbage Root Maggot, we would state that on June 20, 1910, 27 puparia removed from around cabbage plants were placed in a glass vial, and from these 18 specimens of the beetle emerged. It was from some of the material reared at Ottawa in 1910 that Col. Casey decided that the species was not an *Aleochara*, and gave it the name *Baryodma ontarionis*.

The beetle is shown at fig. 26. It is a small, slender, shining black, beetle, in length from about one-eighth to one-quarter of an inch. The legs are paler in colour, inclined to reddish. Wadsworth (13), in 1915, published an interesting account of the life-history of *Aleochara bilineata* Gyll., closely related to the

*Canadian Entomologist, February, 1916.

species here discussed, and one which is also a parasite of the Cabbage Root Maggot. The female beetle deposits its eggs in the soil probably, as the author referred to states, near the roots of cabbages, etc. In from 10 to 12 days the beetle larvæ hatch and they enter the earth in search of the Cabbage Root Maggot puparia upon which they feed.

Cothonaspis gillettei Wash.—This small, black, four-winged cynipid fly, in some years, is very abundant in eastern Canada. In 1910, we reared, at Ottawa, Ont., from the puparia of the Cabbage Root Maggot, numbers of the parasite, the dates of emergence being August 10th to September 6th. Fletcher (12) refers to a cynipid parasite under the name *Eucoila anthomyiæ* Ashm. which is probably the same insect which we reared in 1910. At our Entomological Field Station at Agassiz, B.C., we have also found the species in the middle of June in the soil in association with the Cabbage Root Maggot. In 1915, 12 specimens

IG. 27.—*Cothonaspis gillettei* Wash., a cynipid parasite of the Cabbage Root Maggot. (Original).

were reared, from a large number of collected puparia, between the dates of August 16 and October 18. At Edmonton, Alta., Mr. Donald Mackie, Alberta Department of Agriculture, reared the parasite in July, 1914, and forwarded specimens to the Entomological Branch. We are indebted to Dr. L. O. Howard, Chief of the U. S. Bureau of Entomology, for the determination of specimens from the above localities, which was made by Mr. J. C. Crawford. This cynipid parasite, it will be seen, has a wide distribution in Canada. It is illustrated at figure 27.

Pachycrepoideus dubius Ashm.—In 1910, this chalcid was reared at Ottawa, Ont., in a breeding jar containing puparia of the Cabbage Root Maggot, the date of emergence being August 14.

Ichneumonid parasites.—These four-winged flies are important parasitic insects and help materially in reducing outbreaks of various kinds of injurious insects. In our breeding experiments, both at Ottawa, Ont., and at Agassiz B.C., we have not reared any ichneumonid insects from root maggot material. The only record we have of a parasite of the family Ichneumonidæ having been reared in Canada is a specimen from the Cabbage Root Maggot, forwarded by Mr. D. Mackie, of the Alberta Department of Agriculture, and bred by him at Edmonton, Alta. This specimen, unfortunately, is not a perfect example, but Dr. L. O. Howard, Chief of the U. S. Bureau of Entomology, to whom the specimen was submitted, reported that Mr. Rohwer, who studied it, thought the species to be *Hemiteles ruficoxus* Prov. Unfortunately, only one specimen was reared, and as this is not a perfect example it is difficult to make a positive determination. It is known, however, that the Cabbage Root Maggot is occasionally preyed upon by parasitic insects of the above family.

PREDACIOUS INSECTS.

A predacious insect is one that actually feeds upon and devours another insect, either wholly or in part, thus differing from a true parasitic insect which lives on or within the body of the host, ultimately causing its death.

The relation between root maggots and their parasites is dealt with on page 51. From the standpoint of the control of root maggots by predacious insects we are able to claim that such insects are of most decided benefit and of practical use to the farmer and vegetable grower. The insects shown in figures 28 and 29 may be taken as types of these kinds of beneficial insects which the grower should as far as possible protect. They may be observed actively running over the surface of the soil, hiding under debris in the fields and usually feeding when not disturbed. The insects we have discovered to be predacious on the Cabbage Root Maggot are several carabid and staphilinid beetles. The carabid beetles, of course, are well known predacious insects, and a long list of species which might feed upon root maggots could be prepared. In our work at Agassiz, B.C., we studied only those species of carabid beetles which were actually seen in the act of devouring maggots in the field or were observed in such close association with infested roots that little doubt remains that they were attacking the larvæ.

The following species were taken in this connection and under experiment in the laboratory readily devoured the eggs, the larvæ and often the hard-shelled puparia:

Bembidium mutatum G. & H.* This beetle was the most abundant species observed, being commonly found during the entire season, especially during the month of June and July. In size this insect is one-eighth of an inch in length, shining black in colour, with a conspicuous yellowish spot on the side of each wing-cover near the thorax. It was seen to be very active in movement.

Bembidium trechiforme Lec.* Also commonly seen and occurring with the above. It is a larger species, measuring about one-sixth of an inch in length, black in colour, with yellowish legs.

Platynus cupreus Dej.* Found frequently inhabiting the soil in cabbage plantations. It is a somewhat slender-bodied insect, measuring two-fifths of an inch in length, with the head 1.5 mm. in width, thorax 2.5 mm. wide and elytra or wing covers 4 mm. wide. Thus, as is characteristic of the beetles of this genus, the elytra are nearly twice as wide as the thorax. The beetle is metallic, with a coppery sheen.

Pterostichus lucublandus Say.* Beetles of the genus *Pterostichus* are commonly met with throughout Canada, and constitute one of the most useful genera. The species *lucublandus* is variable in colour, ranging from greenish-blue to reddish, with a purplish sheen. The head and thorax are more highly polished than the wing covers. The length of the insect is about half an inch; the width of head is 2 mm., and the thorax and wing covers about 4.5 mm. The under surface of the body is dull blackish, with the legs reddish. The species is illustrated at figure 28.

Amara (*Celia*) *farcta*.† This beetle occurs commonly in British Columbia. It is also recorded in our Entomological Bulletin No. 8 as predacious on the Strawberry Root Weevil. In general appearance it is very similar to *Pterostichus lucublandus*, with the exception that it is more oval in outline. In length

FIG. 28.—The carabid beetle, *Pterostichus lucublandus* Say. (Original).

it is about 10 mm. and between 4 and 5 mm. wide; shiny, blackish in colour with a coppery sheen.

The staphylinid beetles are a group of insects which normally feed on decaying vegetable and animal matter. An interesting divergence, however, from such usual habits by one species, namely *Baryodma ontarionis* Csy, is recorded in the discussion of the parasites on page 52. From our work at Agassiz, B.C., we are inclined to believe that the species discussed below are truly predacious in the field under strictly natural conditions. They have been seen imbedded in the decaying tissue of cabbage roots on many occasions and when in such positions have sometimes been observed at work devouring maggots. It was never possible to state with assurance that the staphylinid beetles attacked maggots primarily; however, were it not for the fact that such kinds of beetles are known to prefer decaying to fresh food, we should have little hesitation in stating that they are certainly predacious. When the above beetles were removed from the field to artificial glass cages in the laboratory there was no question of their predacious habits. They readily attacked, at any time, fresh live maggots which were introduced. Further, when deprived of food for several days they became cannibalistic in habit.

*Determined by Col. T. L. Casey. †Determined by Dr. E. C. Van Dyke.

The species we record from Agassiz, B.C., as probably predacious are the following:

Orus punctatus Casey.* A very small elongate beetle about one-eighth of an inch long, the head, thorax and abdomen being about equal in width. The colour is black, slightly but uniformly polished on head, thorax and elytra. The legs are brownish-yellow.

Xantholinus hamatus Say.* This was the most commonly-occurring species noticed at Agassiz. In length it is about one-sixth of an inch, and of a uniform width of about one-twenty-fifth of an inch. In colour it is black, the under surface being brownish. It is shown at figure 29.

Fig. 29.—The staphylinid beetle, *Xantholinus hamatus* Say. (Original).

Hesperobium californicum Lec.* In length this beetle is about one-third of an inch long and slender in shape; the head and abdomen are slightly wider than the thorax. The colour is black, shiny, excepting the wing covers which are dull and heavily punctured. The legs are yellowish-brown.

Dinaræa angustula Gyll.** In addition to the above the following record is of interest. On September 25, 1913, we received from Winnipeg, Man., some cabbage plants infested by the Cabbage Root Maggot. With the material was a specimen of the staphylinid beetle, *Dinaræa angustula* Gyll. This species is small and slender, measuring one-eighth of an inch in length. The head thorax and abdomen are black, the elytra, or wing covers, and legs being of a pale yellowish-brown colour.

Red Mite. We have observed frequently a small scarlet mite about the surface of the soil, particularly during recent years, at Agassiz, B.C. Washburn, in Minnesota, in 1906, recorded the value of the species known as *Trombidium scabrum* in destroying the eggs of the Cabbage Root Maggot Fly. Unfortunately,

*Determined by Col. T. L. Casey.
**Determined by Dr. A. Fenyes.

the species observed by us has not, as yet, been determined, but from observations which we have thus far made under laboratory conditions they were, of course, predacious on the eggs, but it would seem that unless these mites become very much more abundant than they have occurred in recent years, their value in controlling the Cabbage Root Maggot would not be very appreciable.

ACKNOWLEDGMENTS.

The authors take pleasure in acknowledging the help they received from student assistants in connection with experiments conducted on the control of root maggots. At Ottawa Messrs. E. W. Calvert, S. N. Lord and T. Rankin, kept notes on planting, applications of insecticides, and harvesting of crops, and at Agassiz, B.C., the same work was done by Messrs. H. S. Brodie and E. Jones. Both of these latter assisted in the tedious daily observations on egg-deposition by the Cabbage Root Maggot Fly.

They also desire to thank Dr. J. T. Wadsworth, of Manchester, Eng., for the photographs from which figures 7 and 8 were made; Dr. F. T. Shutt, Dominion Chemist, of Ottawa, Ont., for the print from which figure 18 was reproduced, and Dr. W. E. Britton, of New Haven, Conn., for the photograph from which figure 20 was made, this latter being originally used to illustrate an article on The Cabbage Root Maggot, by Mr. Q. S. Lowry, in the Fourteenth Report of the State Entomologist of Connecticut.

They are indebted to Dr. J M. Aldrich, Col. T. L. Casey, Dr. E. C Van Dyke, Dr. A. Feynes, Mr. J. C. Crawford and Mr. S. A. Rohwer, for the determination of insects referred to in this bulletin.

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